3. HAZARD AND ACCIDENT ANALYSIS

3.1 Introduction

The purpose of this Feasibility Study Preliminary Documented Safety Analysis (FS-PDSA) is to support remedial decisions for Operable Unit (OU) 7-13/14. Operable Unit 7-13/14 comprises the comprehensive remedial investigation and feasibility study for Waste Area Group (WAG) 7 at the Idaho National Engineering and Environmental Laboratory (INEEL). Waste Area Group 7 is the Radioactive Waste Management Complex, which includes the Subsurface Disposal Area (SDA), a storage area for transuranic (TRU) waste, and miscellaneous support operations.

Information developed throughout the remedial investigation/feasibility study process is cumulatively evaluated to assess data collection activities, assumptions, and the overall strategy for completing the remediation of WAG 7. Administrative implementability is an uncertainty associated with candidate technologies for remediating the SDA. This FS-PDSA provides the basis for evaluating the safety issues and concerns associated with the technology and its implementation in the SDA. This FS-PDSA is not approved for construction per the requirements of 10 CFR 830 Subpart B.

The methodology and results of the hazard analysis for in situ grouting (ISG) are presented in this chapter. The baseline assumption for this assessment is no pretreatment of the buried waste and that the ground and buried waste are at normal ambient temperature. Because ISTD is being considered as a pretreatment for some areas that will subsequently be stabilized by grouting, the effects from having been pretreated will be also be considered as an option.

The hazard analysis considers two alternatives for ISG:

1. In situ grouting would be done in the TRU pits and trenches, low-level waste (LLW) pits and trenches, and soil vaults. This first option is the enveloping case, since it includes all hazardous materials and hazards in the SDA that could affect grouting. All the analyses in this chapter will apply to this alternative unless specifically identified as applying to early action.

   TRU Pits 4, 5, 6, and 10 are being considered for ISTD pretreatment. They contain organic sludges, nitrate sludges, combustible solids, and graphite wastes, all of which are contaminated with plutonium. The safety analysis for performing ISTD has been performed in a separate FS-PDSA[1] however, the impact on ISG of having been pretreated by ISTD will be discussed for this alternative.

2. In situ grouting would be done only in the LLW pits, trenches, and soil vaults. This second option would be done as an early action to accelerate stabilization of the SDA. This second option is less severe because it does not need to consider hazards uniquely associated with the TRU pits and trenches. In situ thermal desorption is only being considered for TRU pits, so it will not be evaluated for early action areas.

3.2 Requirements

The following regulations and U.S. Department of Energy (DOE) orders apply to this subsection:

- 10 CFR 830 Subpart B, "Safety Basis Requirements"

- DOE G 421.1-2 Implementation Guide for Use in Developing DSAs to Meet Subpart B of 10 CFR 830

- DOE Order 420.1A, "Facility Safety"

- DOE Order 5480.23, "Nuclear Safety Analysis Reports"

- DOE-ID Order 420.D, "Requirements and Guidance for Safety Analysis"

- DOE-STD-1027-92, "Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports"

- DOE-STD-3009-94, "Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses."

3.3 Hazards Analysis

This section describes the hazard identification and evaluation performed for ISG. Hazards and associated accidents are identified and grouped (binned) in accordance with DOE-STD-3009-94. This discussion leads to the selection of a limited set of bounding Design Basis Accidents that are further evaluated.

3.3.1 Methodology

This subsection presents the methods used to identify and characterize hazards and to perform a systematic evaluation of basic accidents.

3.3.1.1 Hazard Identification. A hazard is defined as a source of danger (i.e., material, energy source, or operation) with the potential to cause illness, injury, or death to personnel, or damage to an operation or the environment. Hazards are determined without considering the likelihood or credibility of accident scenarios or consequence mitigation. Reviewing the following identified potential hazards:

- Existing safety documentation

- Designs and process descriptions

- Operating history

- U.S. Department of Energy Occurrence Reporting and Processing System (ORPS) computer database.

A "what-if," checklist-type analysis was performed to identify hazards. The result of this hazard identification process is a comprehensive list of applicable hazards.

3.3.1.2 Hazard Evaluation. A qualitative hazard evaluation was performed for the hazards that can result in an uncontrolled release of radioactive or hazardous material and affect the off-site public, collocated workers, facility workers, or the environment.

The likelihood of each hazard without controls is qualitatively estimated using the definitions in Table 3-1. No credit is taken for controls (design or administrative) that prevent or mitigate the scenario. The likelihood category is based on available data, prior studies, operating experience, and engineering

Table 3-1. Qualitative likelihood categories.

Likelihood Category	Description	Frequency of Occurrence (annually)
Anticipated	Events that have occurred or are expected to occur during the lifetime of the facility (frequency between once in 10 and once in 100 years).	10^{-2} to 10^{-1}
Unlikely	Events that may occur but are not anticipated in the lifetime of the facility (frequency between once in 100 and once in 10,000 years).	10^{-4} to 10^{-2}
Extremely unlikely	Events that, while possible, will probably not occur in the lifetime of the facility (frequency between once in 10,000 and once in 1,000,000 years).	10^{-6} to 10^{-4}
Beyond extremely unlikely	Events that are considered too improbable to warrant further consideration (frequency less than once in 1,000,000 years).	$<10^{-6}$

judgment. Scenarios caused by human error are generally assigned to the anticipated category in the absence of controls (e.g., assuming no procedures or training). Unless there are specific failure rate data or history that justify a different likelihood category, scenarios caused by equipment failure are generally assigned to the anticipated category. If there is uncertainty in the likelihood category, the higher-frequency category will be conservatively assumed. The consequence categories are defined in Table 3-2. The numerical consequence category guidelines for the off-Site public located at the site boundary nearest the RWMC, collocated workers assumed to be located 100 m from the release point, and facility workers are based on the evaluation guidelines and criteria for the selection of safety SSCs and TSRs established for INEEL nonreactor nuclear facilities using DOE Order 420.D.

A qualitative estimate of the potential unmitigated consequences to the off-Site public, collocated workers, facility workers, and the environment is made for each hazard. Unmitigated means that a material's quantity, form, location, dispersibility, and interaction with available energy sources are considered, but no credit is taken for safety features (e.g., ventilation system and fire suppression) that could prevent or lessen a hazard. This does not require ignoring passive design features that confine radioactive or hazardous material, if their failure is not postulated by the initiating scenario. The qualitative estimates of consequence category are based on developed estimates or engineering judgment. If there is uncertainty in the consequence category, then the more severe consequence category is assumed.

Based on the likelihood and consequence categories, a risk bin number is assigned using the qualitative risk matrices in Figures 3-1, 3-2, and 3-3. There is no risk bin for environmental effects because environmental protection is not specifically addressed by the evaluation guidelines and only environmental controls are necessary to manage the risk to the environment. Environmental controls are determined based on a qualitative assessment of the likelihood of the scenario and the potential consequences to the environment. The risk bin numbers in the risk matrices indicate whether safety SSCs, TSRs, or safety requirements should be identified to manage the risk.

Potential scenarios initiated by natural events are evaluated in accordance with the requirements and guidelines in DOE Order 420.1A and the referenced DOE standards.

Table 3-2. Quantitative consequence categories.

Consequence Category	Off-Site Public[a]	Collocated[b] Workers	Facility Workers[c]	Environment
High (H)	>25 rem[d] or >ERPG[c]-2	>100 rem[d] or > ERPG[c]-3 or >Δ10 psi[f]	>100 rem[d] or >ERPG[c]-3 or >Δ10 psi[f]	Off-Site contamination or major liquid release to the groundwater.
Moderate (M)	5 to 25 rem[d] or ERPG[c]-1 to ERPG[c]-2	25 to 100 rem[d] or ERPG[c]-2 to ERPG[c]-3	25 to 100 rem[d] orERPG[c]-2 to ERPG[c]-3	On-Site contamination.
Low (L)	0.5 to 5 rem[d] or TLV-TWA[g,h] to ERPG-1	5 to 25 rem[d] or ERPG[c]-1 to ERPG[c]-2	5 to 25 rem[d] or ERPG[c]-1 to ERPG[c]-2	Site area contamination outside the facility.
Negligible (N)	<0.5 rem or <TLV-TWA[g,h]	<5 rem[d] or <ERPG[c]-1	<5 rem[d] or <ERPG[c]-1	No contamination outside the facility.

a. The off-Site public is a hypothetical maximally exposed individual at the nearest INEEL Site boundary.
b. The collocated worker is located outside the facility and is assumed 100 m from the release.
c. The facility worker is inside the facility (e.g., in the immediate vicinity of the release).
d. Radiation doses (rem) are TEDE.
e. Emergency response planning guideline values are intended to provide estimates of concentration ranges where one might reasonably anticipate observing adverse effects, as described in the definitions of ERPG-1, ERPG-2, and ERPG-3 as a consequence of exposure to the specific substance.

The ERPG-1 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing other than mild transient adverse health effects or perceiving a clearly defined, objectionable odor.
The ERPG-2 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing irreversible or other serious health effects or symptoms that could impair an individual's ability to take protective actions.
The ERPG-3 is the maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to 1 hour without experiencing or developing life-threatening health effects.

f. Explosion overpressure is expressed as the differential pressure (Δ psi) of the shock wave from a detonation.
g. The TLV-TWA is the TWA concentration for a normal 8-hour workday and a 40-hour workweek to which nearly all workers may be repeatedly exposed, day after day, without adverse effects.
h. If a TLV-TWA or ERPG value for a specific substance has not been established, TEELs are used. The TEELs for specific chemicals are taken from *ERPGs and TEELs for Chemicals of Concern*.[2]
ERPG = Emergency Response Planning Guide
INEEL = Idaho National Engineering and Environmental Laboratory
TEDE = total effective dose equivalent
TEEL = temporary emergency exposure limit
TLV–TLW = threshold limit value-time-weighted average

3.3.2 Hazard Analysis Results

This subsection identifies the applicable hazards, and includes the hazard categorization. The safety-significant SSCs and the major features for worker safety and protection of the environment are discussed. Unique and representative accidents are identified, based on the results of this hazard evaluation.

3.3.2.1 Hazard Identification. This section describes the results of the hazard identification process.

3.3.2.1.1 ORPS Database Review—Table 3-3 summarizes applicable occurrences from the DOE ORPS database. These events suggest potential safety concerns with the high pressure grouting system and personnel contamination from containment failures and containment maintenance.

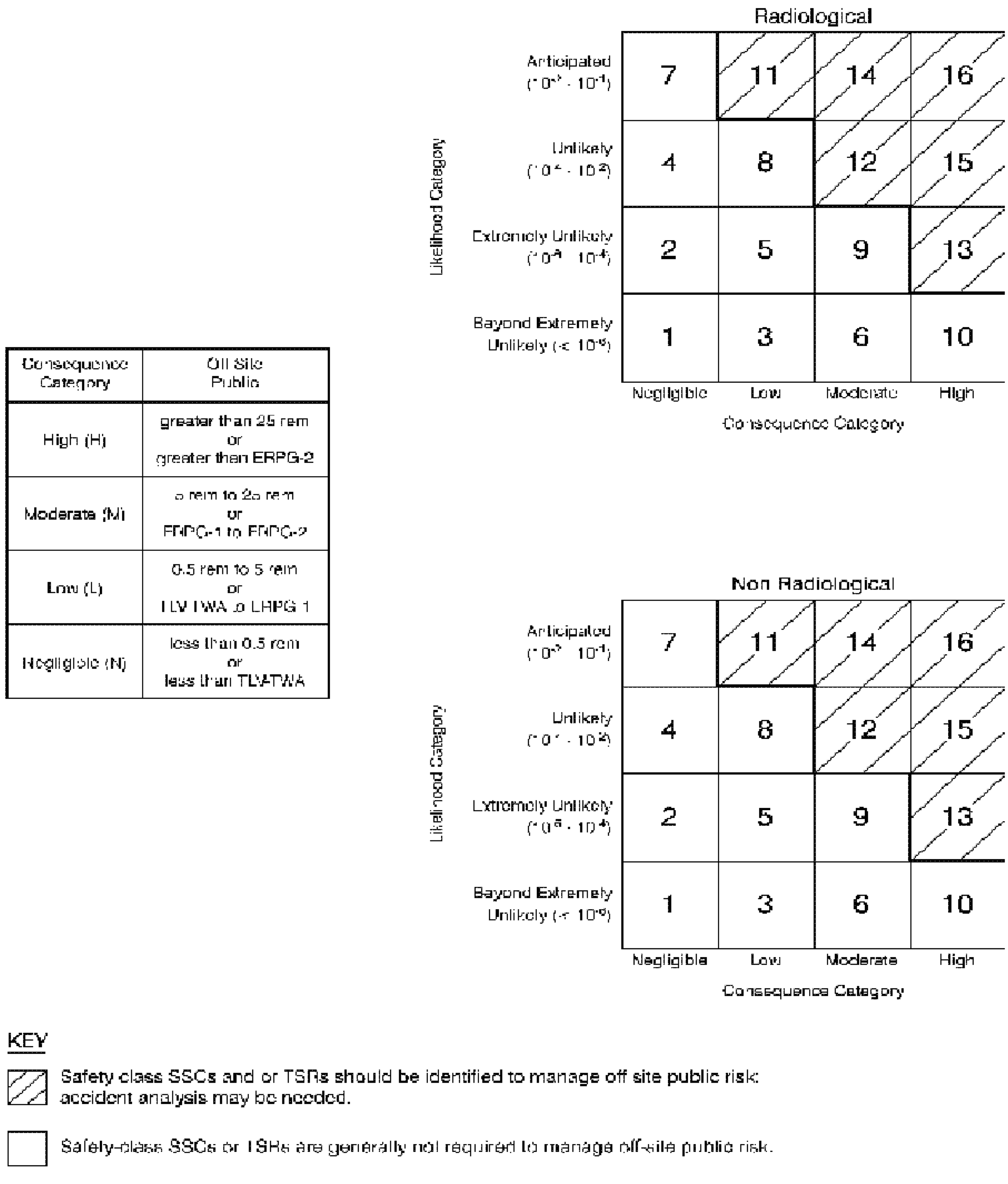
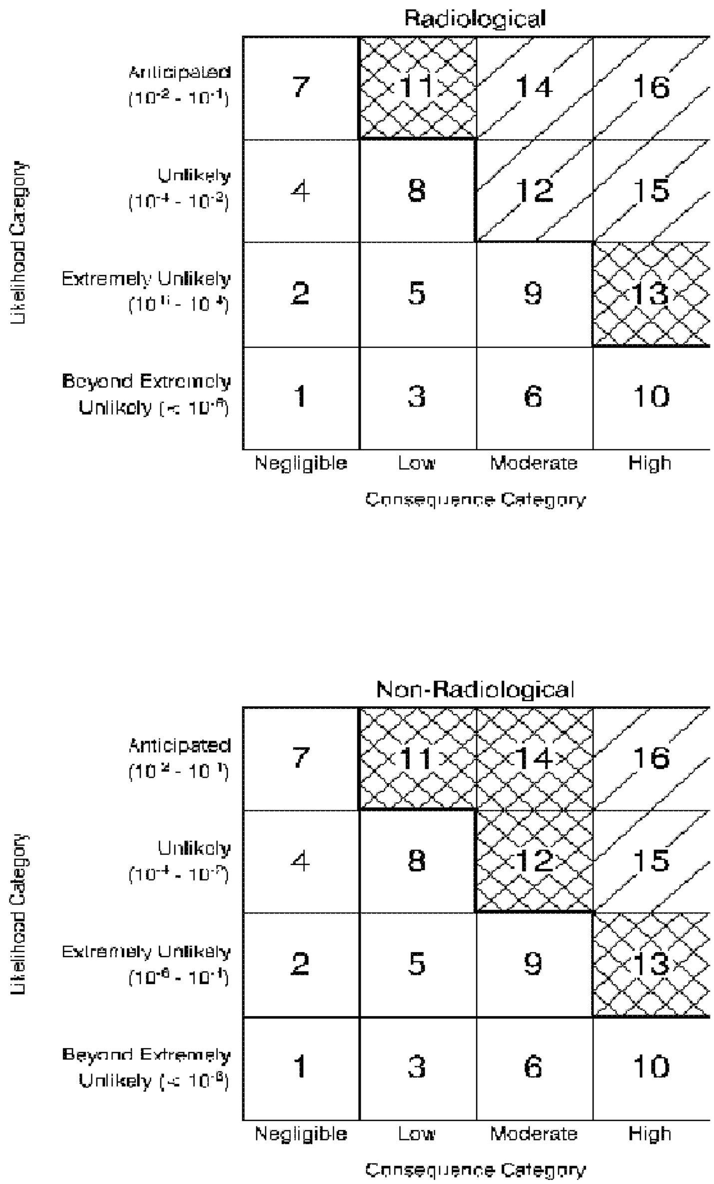


Figure 3-1. Qualitative risk matrices for the off-Site public.



Consequence Category	On-Site (Co-located) Workers
High (H)	greater than 100 rem or greater than ERPG-3 or greater than 10 psi
Moderate (M)	25 rem to 100 rem or ERPG-2 to ERPG-3
Low (L)	5 rem to 25 rem or ERPG-1 to ERPG-2
Negligible (N)	less than 5 rem or less than ERPG-1

KEY

- (diagonal hatch) Safety-significant SSCs and/or TSRs should be identified to manage co-located worker risk; accident analysis may be needed.
- (cross hatch) Safety requirements should be identified to manage co-located worker risk.
- (blank) Safety SSCs, TSRs, or safety requirements are generally not required to manage co-located worker risk.

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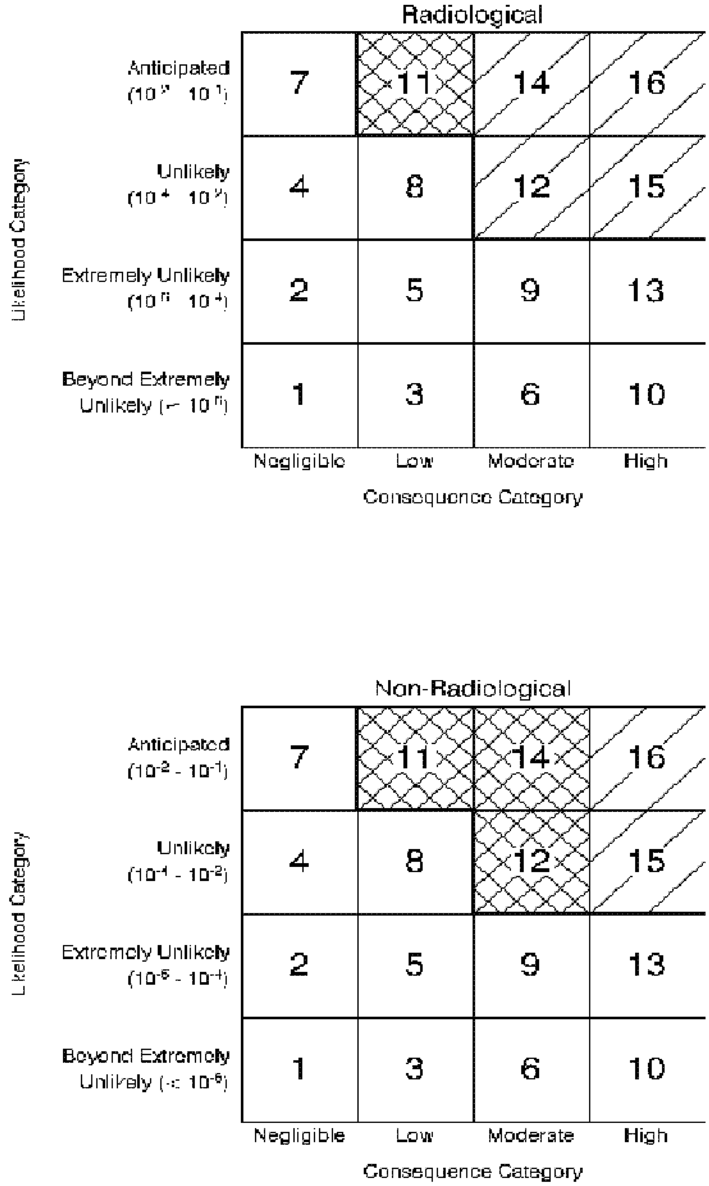
Figure 3-2. Qualitative risk matrices for collocated workers.



Consequence Category	Facility Workers
High (H)	greater than 100 rem or greater than ERPG-3 or greater than ±10 psi
Moderate (M)	25 rem to 100 rem or ERPG-2 to ERPG-3
Low (L)	5 rem to 25 rem or ERPG-1 to ERPG-2
Negligible (N)	less than 5 rem or less than ERPG-1

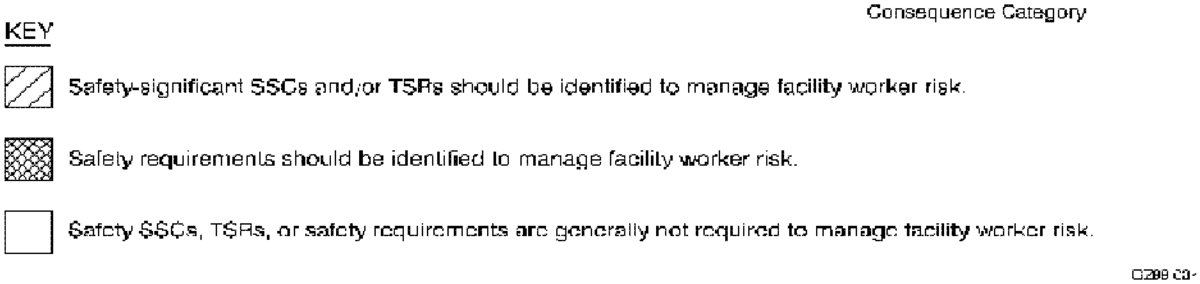


Figure 3-3. Qualitative risk matrices for facility workers.

Table 3-3. Representative and applicable scenarios from the ORPS database.

Report Number	Event Description	Safety Significance
ID-BBWI-RWMC-2001-0028	A subcontractor employee was struck by metal from a ruptured high-pressure fitting during a cold test of ISG. When the grouting system pressure was raised the fittings connecting the high-pressure pump to a pressure/flow sensor failed, resulting in the flying metal.	An under-rated elbow fitting was used in the grout system. Suspect that a clogged replacement drill assembly caused a pressure spike. Pass down of requirements and quality oversight of the subcontractor did not detect the equipment deficiency.
ORO-ME-WSSRAP-1998-0017	A process grout line was pressurized during a sampling activity, spraying contamination into an uncontrolled area. The sampling procedure employed a sample bucket with a lid that was too small to contain the amount of grout released.	The valve used to obtain the grout sample made it difficult to control a small enough sample for the sampling bucket. This event demonstrates that the grouting equipment must be properly designed for all its design requirements to prevent inadvertent releases.
ORO-MMES-X10EVNRES-1992-0001	During field-testing of a grouting procedure, grout pumped into deep soil returned to the surface through an adjacent riser pipe and entered a nearby creek.	Grout may return to the surface in unexpected locations and spread contamination beyond the area boundary.
ID-LITC-RWMC-1999-0001	Certified & Segregated Building blower intake screens frosted over, allowing the fabric to sag and consequently tear because of lower internal air pressure and external snow load.	Work instructions were not communicated to the back shift watch. This occurrence demonstrates the potential for failure of the confinement structure during grouting.
ID-MKF-MKEM-1994-0006	The structural steel skeleton of storage module WMF-633 collapsed during high winds. Steel framework was under construction at the time.	Inadequate design and construction procedures for high wind protection during construction. The occurrence demonstrates the potential for failure of the confinement structure.
ID-EGG-RWMC-1993-0001	The ceiling in WMF-610 was leaking because the roof and ceiling were deformed by excessive snow loading.	The building design and operating procedures did not adequately protect against snow loading. There is a potential for the MCS to be compromised by snow loading or other environmental causes.
ALO-LA-LANL-TA55-1997-0006	Power fluctuation resulted in complete loss of main electrical service and process ventilation at a LANL plutonium handling and processing facility.	Containment ventilation systems that rely on external electrical power are vulnerable to power fluctuations.

Table 3-3. (continued).

Report Number	Event Description	Safety Significance
ALO-LA-LANL-TA55-1997-0020	The process exhaust ventilation for a plutonium processing and handling facility was lost because of adverse weather.	Containment ventilation systems that rely on external electrical power are vulnerable to failure from adverse weather.
RL-WHC-GROUT-1991-0180	Failure of a computer power supply unit caused an unplanned shutdown of the grout processing facility ventilation system.	The grout processing facility does not possess total redundancy in its computer control system. Ventilation systems must be properly designed and unplanned shutdowns can occur.
ID-EGG-RWMC-1993-0006	During removal of soil cover from the side of a cell on the TSAR pad a metal bin containing waste was breached by earthmoving equipment. The damaged container was outside the boundary where waste was expected to be.	Excavation procedures did not adequately protect against the waste container being in an unexpected location. Procedures must allow for the unexpected and breaching of a container is a potential accident.
ALA-LA-LANL-TA55-2000-0009	Airborne release of Pu-238 occurred near a glovebox at LANL. The cause of the release is attributed to a Teflon gasket in the airlock for a glovebox that failed because of radiation degradation and piping not adequately secured at one of the connections.	Plutonium is highly mobile and can escape from any minor breach in containment.
ALO-LA-LANL-TA55-1999-0041	During a glove change out at LANL, a radioactive release triggered a CAM, and all personnel immediately evacuated the area. Nasal smears indicated that the observing RCT received a low-level uptake. None of the observers were wearing respirators.	Maintenance of a containment feature such as a glovebox can result in spreading contamination. Workers must wear adequate personal protective equipment.
ALO-LA-LANL-TA55-1997-0036	A LANL worker was contaminated because of a tear in a Glovebox glove. Two other workers were also in the room when a CAM alarmed. Nasal smears indicated that a worker received a potential low-level plutonium intake. Post-alarm surveys and inspections indicated that the glovebox glove was torn.	The exposed worker had not inspected the glove before beginning work. Because of the location of the tear, the worker may not have seen it even if he had inspected the glove.

LANL = Los Alamos National Laboratory
RCT = radiological control technician
RFP = Rocky Flats Plant

3.3.2.1.2 Checklist—Table 3-4 is a checklist that identifies the applicable hazards (including standard industrial hazards) and DOE-prescribed occupational safety and health standards that prevent or protect against them. Standard industrial hazards are routinely encountered in general industry and construction. For these hazards, national consensus codes or standards (e.g., Occupational Safety and Health Administration) exist to guide safe design and operation. No special analysis of these occupational hazards is required unless they are possible initiators for an uncontrolled exposure to radioactive or nonradioactive hazardous materials or direct radiation. The checklist shows the significant potential concerns in the following areas that are addressed further:

- High-pressure grouting system
- Contact with pressurized, flammable, pyrophoric, or explosive materials in the buried waste
- Direct radiation exposures resulting from removing the soil overburden
- Exposure to buried nonradioactive hazardous materials
- Exposure to buried radioactive hazardous materials
- Potential criticality from fissile materials
- Confinement damage from natural phenomenon such as range fires, earthquakes, volcanoes, high winds, and floods.

3.3.2.1.3 SDA Inventory—The inventory in the SDA generally consists of solid radioactive waste from the INEEL, the RFP, and other off-site generators. This section discusses the radioactive and nonradioactive inventories that will be used for the hazard and accident analyses in this document.

The total inventory in the SDA is estimated using the Historical Data Task (HDT)[3] and Recent and Projected Data Task (RPDT)[4] reports. The HDT report contains best estimate, lower bound, and upper bound total quantities of radioactive and nonradioactive hazardous materials buried between 1952 and 1983. The RPDT report contains similar historical information for 1984 through 1993, and projected quantities from 1994 through 2003. The RPDT has been updated with the actual disposals to 1999.[5] The total activity for some radionuclides has also been updated to reflect currently accepted values reported in Table 3-7 of the Ancillary Basis for Risk Analysis (ABRA) report.[6] Carbon tetrachloride, tetrachloroethylene, trichloroethylene, and 1,1,1-trichloroethane contents have been updated from a study by Varvel.[7]

The development of these inventories and sources is described in Engineering Design File (EDF)-3543, SDA Inventory Evaluation for ISG, ISV, and ISTD PDSA Source Terms.[8] The EDF addresses all waste types buried in the RWMC SDA, including transuranic (TRU) waste, contact-handled low-level waste (CH-LLW), and remote-handled low-level waste (RH-LLW). It also addresses nonradioactive contaminants that are part of the mixed TRU waste and LLW.

Table 3-4. ISG material and energy hazard identification checklist.

Hazard	DOE-Prescribed Program and Occupational Safety and Health (OSH) Standards	Hazard Source(s)	Concern	Applicable Facilities/Operations	Addressed Further? (Yes/No)[a]
Electrical	29 CFR 1910 Subpart S; National Electric Code (NEC) 70	Electric equipment (>600 VAC)	Electrocution Fire	15.4 kV-armored cable will supply MCS.	No (Yes for fire)
		Electric distribution system and equipment (<600 VAC)	Electrocution Fire	480 V distribution system for the MCS supplies large motors. 120 – 208 V for normal "house" loads. 240 V DC for control and instrumentation.	No (Yes for fire)
		Batteries	Burns, shock, explosion	None.	No
		Buried cable	Electrocution	No buried cables in the SDA where MCS will operate.	No
		On-ground cable	Electrocution	15kV-armored cable across SDA surface to the grouting location.	No
		Low-hanging wires	Electrocution	Low hanging wires outside the SDA. Potential hazard to the MCS when being moved.	No
Volatile flammable or reactive gases or liquids	29 CFR 1910.106, .1200; 29 CFR 1926.152	Propane tank	Asphyxiation, burns, BLEVE, fuel-air explosion	Propane in the SDA is addressed in the RWMC SAR. There are no sources of propane associated with grouting and the MCS.	No
		Flammable/combustible liquids (including oil storage)	Burns	Flammable liquids are buried in the SDA and will be affected by grouting.	Yes
		Gasoline and diesel	Burns	Gasoline and diesel may be used to power vehicles or a diesel generator.	Yes
Explosive materials	29 CFR 1910.109 DOE Explosive Safety Manual (DOE M 440-1)	Hydrogen gas	Explosion	Buried drums may self-generate hydrogen gas that can be released and ignited by drilling into the drums during grouting.	Yes
	29 CFR 1910.109 DOE Explosive Safety Manual (DOE M 440-1)	Mixture of nitrate wastes with organic materials	Explosion	Potential for sodium and potassium nitrate wastes to mix with buried organic materials to form an explosive mixture that would be triggered by a rapid rise in temperature.	Yes

Table 3-4. (continued).

Hazard	DOE-Prescribed Program and Occupational Safety and Health (OSH) Standards	Hazard Source(s)	Concern	Applicable Facilities/Operations	Addressed Further? (Yes/No)[a]
Cryogenic systems	DOE Order 440.1A	Liquid nitrogen	Frostbite	None.	No
Piping and vessels	America Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code, ANSI/ASME Standard B31	Fired and unfired pressure vessels	Projectiles	None.	No
Pressurized liquid systems	None of the DOE-prescribed OSHA standards clearly address the hazards of high-pressure systems	Pressurized grout.	Projectiles and high-pressure contents.	The grout delivery system will be approximately 6,000 psi. There is a potential for the system to fail.	Yes
		Hydraulic system	Projectiles and high-pressure contents	Hydraulic systems will be used to power and control the crawler tracks, leveling system, and drill rig on the MCS.	No
Compressed gas	Compressed Gas Association CGA P-1 (1965), Safe Handling of Compressed Gases	Cylinders of various gases, compressed air supply	Projectiles	Pressurized gas cylinders may be buried in the SDA, where they could be penetrated by drilling.	Yes
Inert and low-oxygen atmospheres	29 CFR 1910.120, .1200 29 CFR 1926.651	Confined space	Asphyxiation	None associated with grouting and the MCS.	No
Toxic Materials	29 CFR 1910.120, .1200, 1926.353; American Conference of Governmental Industrial Hygienists (ACGIH) TLVs	Fixed asbestos	Personnel exposure	None associated with grouting and the MCS.	No
		Carbon monoxide	Personnel exposure	None associated with grouting and the MCS.	No

Table 3-4. (continued).

Hazard	DOE-Prescribed Program and Occupational Safety and Health (OSH) Standards	Hazard Source(s)	Concern	Applicable Facilities/Operations	Addressed Further? (Yes/No)[a]
		Chemical hazards (cleaning, and so forth)	Personnel exposure, poisoning	None associated with grouting and the MCS.	No
		Buried chemicals	Personnel exposure, poisoning	The SDA contains large quantities of buried chemicals that may be released through grouting.	Yes
		Freon 22, Halon	Frostbite, asphyxiation, cardiac effects	None associated with grouting and the MCS.	No
		Lead	Personnel exposure, poisoning	Lead is buried in the SDA.	Yes
		Hazardous (mixed) waste	Personnel exposure, poisoning	The SDA contains large quantities of mixed waste that may be released through grouting.	Yes
		Volatile Organic Compounds	Personnel exposure, poisoning	The SDA contains large quantities of VOCs that may be released through grouting.	Yes
Nonionizing radiation	29 CFR 1910.97; ACGIH TLVs, ANSI Z 136	Not applicable	Not applicable	None.	No
High intensity magnetic fields	ACGIH TLVs	Not applicable	Not applicable	None.	No
High noise levels	29 CFR 1910.95, .1200 29 CFR 1926.52; ACGIH TLVs	High noise from operating equipment	Hearing damage	The grout delivery system and drilling equipment may be high noise equipment.	No
		High noise from operating equipment	Hearing damage	Driving the grout containment piling may produce high noise levels.	No
Mechanical and moving equipment dangers	29 CFR 1910.147, .211 through .219; 29 CFR 1910 Subparts O, P, Q; 29 CFR 1926 Subpart W	Rotating equipment (that is, HVAC equipment, belts, conveyors)	Personnel injury	The MCS tracks and drill rig.	No
		Vehicle/forklift traffic	Impact with personnel	Forklifts may be used for handling grout materials.	No

Table 3-4. (continued).

Hazard	DOE-Prescribed Program and Occupational Safety and Health (OSH) Standards	Hazard Source(s)	Concern	Applicable Facilities/Operations	Addressed Further? (Yes/No)[a]
		MCS bridge crane	Crane failure could cause the high pressure grouting system or the MCS to fail.	The MCS bridge crane, MCS structure, and high pressure grouting equipment.	Yes
Working at heights	29 CFR 1910.25, .28 29 CFR 1926.951, .451	Ladders/platforms, bridges, high equipment, pits	Personnel falling	Working at heights will not be required regularly, but may be required occasionally for crane maintenance.	No
Excavation	29 CFR 1926 Subpart P	Disposal pits	Falls, walls collapsing	Excavations will not be required for grouting.	No
Material handling dangers	29 CFR 1910.120, .176 through .182 29 CFR 1926.953; DOE-STD-1090-2001 Hoisting and Rigging	Cranes, forklifts	Crushing personnel	Material handling will be required to deliver the raw materials for grout mixing and in delivering mixed grout to the MCS.	No
	29 CFR 1910.120, .176 through .182 29 CFR 1926.953; DOE-STD-1090-2001 Hoisting and Rigging	Pile emplacing equipment	Personnel injury	Operating equipment to drive grout containment piling may injure workers.	No
Material transportation (onsite and offsite)	Hazardous Material Transportation Program, DOE Orders 460.1A and 460.2	Hazardous materials	Personnel exposure	Raw materials will be required for making grout, but these are not hazardous materials.	No
Pesticide, herbicide, and rodenticides use	29 CFR 1910.1200	Pesticides, herbicides, rodenticides-	Poisoning	None.	No
Temperature extremes (high and low temperatures during activities)	29 CFR 1910.H120, .Z1200; ACGIH TLVs	Ambient temperatures	Hypothermia, frostbite, heat stress	Extreme cold can occur during the winter months and can damage the flexible components of the passive confinements and freeze process and fire protection water.	No

Table 3-4. (continued).

Hazard	DOE-Prescribed Program and Occupational Safety and Health (OSH) Standards	Hazard Source(s)	Concern	Applicable Facilities/Operations	Addressed Further? (Yes/No)[a]
Inadequate illumination	29 CFR 1910.E37, .F68, .H120, .N177 through .179, .219, .S303 29 CFR 1926.C26	Inadequate lighting	Tripping or falling	None.	No
Construction	29 CFR 1926	General construction hazards	Personnel injury	The MCS will be staged and tested at the RWMC.	No
Ionizing radiation	Occupational Radiation Protection, 10 CFR 835	Radioactive waste	Personnel exposure	The SDA contains large quantities of materials that emit ionizing radiation. Workers could be exposed if the waste is uncovered by subsidence or removing the overburden.	Yes
Radioactive materials	10 CFR 835	Radioactive waste	Personnel exposure	The SDA contains large quantities of materials that are radioactive.	Yes
Fissile materials	DOE Order 5480.24	Radioactive waste	Criticality	The SDA contains large quantities of fissile materials.	Yes
Reactive Materials: Alkali Metal and Corrosives	Chemical Safety Program DOE Order 5480.4; 29 CFR 1910.Z1200, .Z1450	Hazardous buried waste materials	Personnel exposure or injury	The SDA contains a variety of reactive materials and alkali metals in the buried waste.	Yes
Structural or Natural Phenomena	DOE Order 420.1, DOE-ID AE Standards DOE G 420.1-2 29 CFR 1910.H119, Subpart E	Lightning, strong wind, tornado, earthquake, range fires, and so forth	Other material and energy sources listed in this table, these are initiators.	The MCS will be susceptible to structural and natural phenomena.	Yes
Fire	Fire Protection Program, DOE Order 420.1	Combustibles (solids and gases)	Burns	If used, paraffin grout is a combustible material.	Yes
Biological Agents	DOE Order 440.1A	Hantavirus	Personnel exposure	MCS and related support facilities.	No
		Biological assays	Personnel exposure	None.	No
		Sewage	Personnel exposure	None.	No

Table 3-4. (continued).

Hazard	DOE-Prescribed Program and Occupational Safety and Health (OSH) Standards	Hazard Source(s)	Concern	Applicable Facilities/Operations	Addressed Further? (Yes/No)[a]
Other	29 CFR 1910, DOE Order 440.1A	Low overhead	Head injury	None.	No
		Pinch point	Injury to extremities	None.	No
		Uneven or slick walking surfaces, trip/fall hazards	Tripping or falling	Areas in the SDA where grouting is being performed.	No
		Objects at height (for example, shelves, overhead crane work, waste handling)	Objects falling onto personnel	Overhead drill rig in the MCS.	No
		Water heater, boiler, tank, soldering surface	Burns	None.	No
		Hot water used to clean grout delivery system of paraffin grout	Burns	Grout delivery system.	No
		Exhaust pipe	Burns	None.	No
External events	Not applicable	The AMWTP is a potential source for hazards addressed in the previous rows. No hazards unique to AMWTP were identified.	External source of radioactive and hazardous materials.	Areas where grouting is being performed.	Yes[b]
		Aircraft (helicopter and fixed wing) crash	Impact, fire, initiator for another hazard	Areas where grouting is being performed.	Yes

a. This question pertains to further consideration of the hazard identified here and not to initiators for another hazard. All hazards, even those dismissed here, are considered as initiators for other hazards. For example, fires from propane tanks or batteries are not considered further as a direct hazard, but they are considered as initiators for waste fires that could result in release of radioactive or hazardous material.

b. External events are considered as initiators for release of radioactive and chemically hazardous materials.

The areas of interest include the closed pits 1–16, the open pits 17–20, all trenches (1–58), all soil vault rows (1–21), and Pad A. The waste on Pad A will not be treated there, but may be transferred to a pit for disposal and treatment. This inventory does not include TRU waste stored in the TSA.

The source term information presented in this section is for the entire SDA and thus applies to grouting in the entire SDA. The source term information is presented so that inventories in non-TRU early action areas can also be evaluated separately.

If performed, ISTD will reduce the inventory of nonmetallic hazardous materials (organics and nitrates) in the treated areas. Pretreatment is currently planned for Pits 4, 5, 6, and 10. The effectiveness for each type of hazardous material is discussed in the following sections.

3.3.2.1.3.1 Radioactive Material Inventory—The total quantities of radioactive hazardous materials are shown in Table 3-5. The table shows the quantity of each radionuclide disposed for each time period and the total for all time periods. The "Total Best Estimate" activities have been updated to reflect current data from the ABRA report.[6] Because the data from the ABRA report are cumulative, the updated "Total Best Estimate" activity value for a radionuclide is not necessarily equal to the sum of the activity values for the time intervals. Activity levels are those at the time of disposal, without consideration of radioactive decay.

3.3.2.1.3.2 Transuranic Waste—TRU waste is radioactive waste that contains alpha-emitting radionuclides with an atomic number greater than 92 (elements heavier than uranium) and a half-life greater than 20 years. During the period when TRU waste was buried in the SDA, TRU waste was defined to have an activity concentration greater than 10 nCi/g. Transuranic waste is of particular concern because of its long-lived radioactivity and high radiological dose consequences when inhaled. Transuranic waste disposal was terminated at the SDA in 1970.

Subsurface Disposal Area Pits 1–6 and 9–12, and trenches 1–10 are known to contain TRU waste. Trenches 11–15 are also suspected to contain TRU waste. RFP waste in drums and boxes was disposed in Pits 11 and 12 through 1972. Later, these drums were retrieved and the TRU drums were placed in the Transuranic Storage Area. The boxes were left in Pits 11 and 12, so TRU could have been disposed of then. Also, there are a small number of TRU drums on Pad A.

Transuranic waste consists of a wide variety of materials including large quantities of solidified nitrate salt and organic sludges, gloves, paper, plastics, rags, and other combustible wastes; various tools and other light metal or steel wastes; heavy metal wastes (such as tantalum molds and funnels); graphite mold materials (chunks and fines); glass; and other items used in day-to-day RFP glovebox operations.

The majority of metal drums in the SDA is assumed to be breached because of corrosion or physical damage to the drum during dumping and burial, and can no longer provide adequate waste containment of their contents.[9] Although most recent RFP waste drums have a poly drum liner, the poly drum liners were not used until late 1972; therefore, none are assumed present in the SDA. Earlier retrieval efforts did observe some leaking containers indicating unabsorbed or desorbed free liquid in drums.[10]

Table 3-5. Radioactive Hazardous Materials in the RWMC SDA.

Radionuclide	52 - 83 Best Estimate (Ci)	84 - 93 Best Estimate (Ci)	94 - 99 Best Estimate (Ci)	Total Best Estimate (Ci)	Percent of Total Activity (%)
Am-241	1.5E+05	3.7E+00	1.8E+00	1.83E+05	1.3E+00
Pu-239	6.6E+04	2.4E+00	1.8E-01	6.49E+04	4.8E-01
Pu-241	4.0E+05	1.7E+01	1.0E+01	9.74E+05	7.1E+00
Pu-240	1.5E+04	5.7E-02	1.0E-01	1.71E+04	1.3E-01
Pu-238	2.5E+03	3.6E-01	1.7E-01	1.71E+04	1.3E-01
Sr-90	4.5E+05	5.8E+02	6.2E+01	6.44E+05	4.7E+00
Co-60	2.8E+06	1.4E+06	2.8E+04	2.20E+06	1.6E+01
Am-243	2.3E-01	None	6.8E-06	1.34E+02	9.8E-04
Ce-144	1.5E+05	2.1E+02	1.4E+01	1.5E+05	1.1E+00
Cm-244	8.0E+01	7.6E-02	9.2E-02	8.0E+01	5.9E-04
Cs-137	7.0E+05	3.1E+03	7.2E+01	6.17E+05	4.5E+00
U-238	1.1E+02	1.6E+00	1.2E+00	1.17E+02	8.6E-04
Fe-55	3.8E+06	1.6E+05	2.1E+04	4.0E+06	2.9E+01
U-234	6.4E+01	3.5E+00	2.5E+00	6.74E+01	4.9E-04
Ni-63	7.4E+05	4.8E+05	5.3E+04	1.32E+06	9.7E+00
U-232	8.4E+00	2.2E+00	5.1E-03	1.06E+01	7.8E-05
Pu-242	9.9E-01	1.2E-08	4.2E-08	1.65E+01	1.2E-04
Co-58	1.6E+05	2.0E+05	1.9E+03	3.6E+05	2.7E+00
Th-228	None	1.0E+01	7.7E-03	1.02E+01	7.5E-05
Ru-106	6.8E+03	6.4E+01	4.5E+00	6.9E+03	5.0E-02
Th-232	1.3E+00	None	2.6E-02	1.34E+00	9.8E-06
Mn-54	1.8E+05	1.2E+05	2.3E+03	3.0E+05	2.2E+00
Zr-95	7.6E+04	2.1E+03	1.2E+02	7.8E+04	5.7E-01
Sb-125	1.3E+05	2.9E+03	1.5E+03	1.3E+05	9.9E-01
Cm-242	9.1E+01	8.8E-02	1.3E-01	9.1E+01	6.7E-04
Fe-59	9.1E+04	1.5E+04	2.7E+00	1.1E+05	7.8E-01
Np-237	2.4E+00	3.7E-03	9.4E-03	2.64E+00	1.9E-05
Eu-154	3.0E+03	3.3E+00	1.5E+02	3.00E+03	2.2E-02
Ta-182	8.5E+00	1.8E+04	4.1E+02	1.8E+04	1.4E-01
U-235	5.1E+00	1.6E-01	2.7E-01	5.54E+00	4.1E-05
Eu-155	1.5E+04	3.9E+01	8.2E+01	1.5E+04	1.1E-01
Ra-226	5.9E+01	1.1E+00	7.9E-02	6.00E+01	4.4E-04

Table 3-5. (continued).

Radionuclide	52 - 83 Best Estimate (Ci)	84 - 93 Best Estimate (Ci)	94 - 99 Best Estimate (Ci)	Total Best Estimate (Ci)	Percent of Total Activity (%)
Nb-94	4.9E+01	2.0E-01	2.8E-01	1.00E+03	7.3E-03
U-236	2.5E+00	2.3E-03	4.7E-03	2.86E+00	2.1E-05
Cr-51	7.3E+05	4.7E+04	6.1E+02	7.8E+05	5.7E+00
Sn-119m	2.7E+04	8.8E+03	9.1E+00	3.6E+04	2.6E-01
U-233	1.1E+00	None	3.6E-01	1.51E+00	1.1E-05
Y-90	1.9E+04	2.0E+02	2.4E+01	1.9E+04	1.4E-01
Cs-134	2.2E+03	1.4E+02	3.2E+00	2.3E+03	1.7E-02
H-3	1.2E+06	3.0E+05	4.4E+03	1.50E+06	1.1E+01
Co-57	4.8E+00	1.5E+00	7.2E+03	7.2E+03	5.3E-02
Eu-152	2.4E+02	4.1E+00	2.5E+01	2.7E+02	2.0E-03
Hf-181	3.6E-01	3.4E+03	8.4E+00	3.4E+03	2.5E-02
Sb-124	1.8E+03	1.1E-02	5.1E-01	1.8E+03	1.3E-02
Nb-95	2.4E+03	3.8E+03	1.6E+00	6.2E+03	4.6E-02
Zn-65	3.6E+02	1.0E+03	2.2E+03	1.36E+03	1.0E-02
Y-91	5.3E+02	None	8.6E-06	5.3E+02	3.9E-03
Ni-59	5.1E+03	1.4E+03	4.4E+02	6.9E+03	5.1E-02
Sr-89	4.7E+02	3.0E+00	8.8E+00	4.10E+02	3.0E-03
Hf-175	None	2.8E+03	4.2E-02	2.8E+03	2.1E-02
Th-230	1.8E-02	None	1.3E-02	3.13E-02	2.3E-07
Ce-141	7.6E+02	2.9E+00	1.5E-01	7.6E+02	5.6E-03
Pr-143	6.2E+02	None	None	6.2E+02	4.6E-03
W-185	None	6.4E+03	None	6.4E+03	4.7E-02
Pm-147	8.1E+01	2.4E+00	2.6E+01	1.1E+02	8.1E-04
Sc-46	5.3E+01	5.0E+01	3.4E+01	1.4E+02	1.0E-03
La-140	7.7E+02	2.8E+00	6.6E-02	7.7E+02	5.7E-03
Ir-192	5.4E+01	6.6E-01	7.0E+01	1.2E+02	9.1E-04
Ru-103	3.6E+02	1.9E-01	1.1E-02	3.6E+02	2.6E-03
Na-22	3.0E-01	5.4E-01	3.7E+02	3.7E+02	2.7E-03
Ba-140	6.6E+02	2.4E+00	6.8E-02	6.6E+02	4.9E-03
Pr-144	4.2E+04	1.1E+02	2.2E+00	4.2E+04	3.1E-01
Cf-252	1.0E-02	None	None	1.0E-02	7.3E-08
Be-10	4.3E+01	None	1.0E-10	4.3E+01	3.2E-04
Zr-93	4.0E+00	None	3.1E-05	4.0E+00	2.9E-05

Table 3-5. (continued).

Radionuclide	52 - 83 Best Estimate (Ci)	84 - 93 Best Estimate (Ci)	94 - 99 Best Estimate (Ci)	Total Best Estimate (Ci)	Percent of Total Activity (%)
C-14	1.6E+04	4.0E+01	1.8E+01	5.00E+02	3.7E-03
Cd-109	4.1E-01	1.1E-02	5.2E-04	4.2E-01	3.1E-06
Tc-99	2.6E+02	5.0E-01	9.0E-01	6.05E+01	4.4E-04
Sn-117m	None	1.2E+02	1.7E-09	1.2E+02	8.8E-04
Te-125m	None	4.2E+01	1.0E-02	4.2E+01	3.1E-04
Sn-113	None	2.4E+01	4.6E+00	2.9E+01	2.1E-04
Tm-170	3.4E+00	None	None	3.4E+00	2.5E-05
I-131	1.5E+00	1.1E-01	6.0E-02	1.7E+00	1.2E-05
Rb-86	7.1E+00	None	None	7.1E+00	5.2E-05
Gd-153	None	1.3E+00	8.7E-02	1.4E+00	1.0E-05
I-129	9.9E-02	2.1E-03	5.3E-03	1.58E-01	1.2E-06
Cl-36	3.1E-01	None	9.2E-02	1.11E+00	8.1E-06
Ag-108m	None	1.1E-07	7.1E-02	7.1E-02	5.2E-07
Mn-56	2.7E+01	1.3E+00	None	2.8E+01	2.1E-04
Cs-136	7.7E-01	None	None	7.7E-01	5.7E-06
Mo-99	1.0E+00	2.3E-02	2.2E-02	1.0E+00	7.7E-06
Na-24	None	2.7E+00	1.6E-02	2.7E+00	2.0E-05
Ag-110m	None	1.8E-02	2.8E-01	3.0E-01	2.2E-06
V-48	None	2.0E-01	None	2.0E-01	1.5E-06
P-32	9.2E-02	None	1.4E-11	9.2E-02	6.8E-07
Rh-103m	2.7E+02	None	1.3E-02	2.7E+02	2.0E-03
Y-88	2.5E-02	3.0E-03	7.1E-05	2.8E-02	2.1E-07
I-125	2.9E-02	None	8.2E-04	3.0E-02	2.2E-07
Se-75	None	4.5E-02	2.9E-02	7.4E-02	5.4E-07
Am-242	7.6E-03	None	None	7.6E-03	5.6E-08
I-132	None	1.0E+00	1.5E-01	1.2E+00	8.4E-06
I-133	5.0E-02	1.5E-03	None	5.2E-02	3.8E-07
S-35	8.8E-02	None	1.2E-02	1.0E-01	7.4E-07
Y-93	None	1.1E-01	None	1.1E-01	8.1E-07
Sr-85	2.9E-02	None	7.8E-04	3.0E-02	2.2E-07
Be-7	3.5E-01	None	None	3.5E-01	2.6E-06
Hg-203	1.2E-02	None	None	1.2E-02	8.8E-08
Po-210	7.5E+01	None	5.1E-07	9.10E-06	6.7E-11

Table 3-5. (continued).

Radionuclide	52 - 83 Best Estimate (Ci)	84 - 93 Best Estimate (Ci)	94 - 99 Best Estimate (Ci)	Total Best Estimate (Ci)	Percent of Total Activity (%)
Au-198	None	2.4E-02	None	2.4E-02	1.8E-07
Te-132	None	5.6E-03	6.7E-17	5.6E-03	4.1E-08
Ra-225	2.0E-06	None	2.5E-06	4.5E-06	3.3E-11
Pb-212	2.0E-05	None	1.7E-04	1.9E-04	1.4E-09
Re-188	None	9.3E-03	None	9.3E-03	6.8E-08
Er-169	7.6E-03	None	None	7.6E-03	5.6E-08
Sc-44	2.5E-02	None	None	2.5E-02	1.8E-07
Sr-91	None	4.4E-03	None	4.4E-03	3.2E-08
Pb-210	9.1E-06	None	5.1E-07	5.10E-07	3.7E-12
Ba-133	5.4E-04	None	3.4E-04	8.8E-04	6.4E-09
Ca-45	6.7E-04	None	None	6.7E-04	4.9E-09
In-113m	None	8.2E-02	6.4E-04	8.3E-02	6.1E-07
Ce-139	None	3.0E-04	2.8E-06	3.0E-04	2.2E-09
Tl-204	6.7E-04	None	None	6.7E-04	4.9E-09
Br-82	None	1.0E-03	None	1.0E-03	7.3E-09
Sr-92	None	1.6E-03	None	1.6E-03	1.2E-08
Mn-53	1.0E-03	None	None	1.0E-03	7.3E-09
Cd-104	1.5E-07	None	None	1.5E-07	1.1E-12
Ag-110	8.4E-01	1.9E+00	5.9E-03	2.7E+00	2.0E-05
Ba-137m	3.4E+00	4.6E+00	8.5E+00	1.6E+01	1.2E-04
Kr-85	1.3E+00	None	1.9E-03	1.3E+00	9.6E-06
Rh-106	6.8E+03	6.1E+01	1.8E+00	6.9E+03	5.0E-02
Rn-222	1.0E-06	None	5.8E-07	1.6E-06	1.2E-11
Xe-133	None	None	None	None	None
Yb-164	7.6E-03	None	None	7.6E-03	5.6E-08

The radioactive material inventory for accidents involving TRU drums with likelihood categories of anticipated, unlikely, and extremely unlikely are shown in Table 3-6. Information about drum inventories has been derived from the following:

- Acceptable knowledge reports based on shipping records
- Data from assaying stored drums being shipped to the Waste Isolation Pilot Plant (WIPP)
- Data from SDA subsurface probes.

Table 3-6. Drum inventory for accident scenarios involving a single TRU drum.

	Mass Content (grams)		Activity Content (curies)		
Single Drum Cases	Pu-239-eq	Am-241	Pu-239-eq	Am-241	Data Source
Upper Bound Drum (extremely unlikely)	2217	71	140	240	Probe Data for Pu Acceptable knowledge for Am[11]
Limiting Drum (unlikely)	510	31	31.8	105	Haefner Report[12] for Pu-equiv Acceptable knowledge for Am
Best estimate Drum (anticipated)	58	0.22	3.6	0.74	Haefner Report for Pu-equiv Acceptable knowledge for Am

Notes:
Pu-239-eq is amount Pu-239 equivalent to a quantity of Rocky Flats plutonium (Pu-238 through Pu-242 isotopes and ingrown Am-241).[12]
Use either Pu-239-eq or Am-241, but not both. Haefner report includes Am-241 in calculating Pu-239-eq. For upper bound and limiting drums, finding both limiting inventories in the same drum is considered beyond extremely unlikely. A best estimate drum would be expected to contain either Pu-239-eq or Am-241 alone, but not both.
Pu-239-eq curies converted to grams using 0.062 Ci Pu-239-eq / gm. Pu-239-eq from Haefner.

If ISTD pretreatment is performed, it is planned for TRU pits 4, 5, 6, and 10. The ISTD process will not destroy TRU radionuclides, but some may be swept out of the subsurface and into the off-gas system by the process gasses. The quantity removed has not been estimated, but since the gas velocities are low and plutonium and americium are not mobile in the soil and waste matrix, it is estimated to be small; thus, ISTD will not significantly reduce the TRU radionuclide inventory.

3.3.2.1.3.3 Direct Radiation Sources—SDA shipping records show the SDA pits and trenches contain 861 packages with surface radiation exposure rates above 1 R/hr at the time of disposal. Exposure rates for materials in the soil vaults have not been characterized, but are expected to be similar. Sixty-seven of the packages in the pits and trenches had surface exposure rates of 100 R/hour or greater. Most of the RH sources are from the INEEL. Only eight of these packages were buried in the pits, with the rest in trenches. The last RH disposal in a trench was September 25, 1981. After that, RH packages were disposed of in soil and concrete vaults. The predominant known isotope is Co-60. The unknown isotopes are also believed to be mostly Co-60, but include a variety of fission and activation products.

The highest exposure package was 150,000 R/hr at the surface. Since it is identified as Co-60 with a disposal date of January 17, 1963, its current exposure rate is approximately 800 R/hr. The next highest surface exposure rate is 24,000 R/hr from unknown isotopes. Since the isotopes are unknown, decay cannot be accurately calculated; thus, the direct radiation surface exposure rate for potential accident calculations is conservatively bounded at 24,000 R/hr. Remote-handled LLW was disposed in many different packages and configurations. The largest commonly used package was an internal canister that fits the 55-ton cask. The package has a diameter of 46.6 in. Thus, it is conservatively assumed the surface of the 24,000 R/hr package is 2 ft from the center axis.

In situ thermal desorption pretreatment is not expected to have any effect on the direct radiation sources. They are not buried in the pits planned for pretreatment, and the sources are generally solid metal items that would not melt at ISTD temperatures.

3.3.2.1.3.4 Non-TRU Waste—Non-TRU waste is LLW that contains beta- and gamma-emitting radionuclides. Low-level waste is still being disposed. Low-level wastes from the

INEEL are in all pits and trenches, and include activation products and fission products from reactor operations at the Site. The wastes include various reactor core, vessel, and loop components, and resins and discarded laboratory materials. Irradiated fuel materials and contaminated metal and debris from demolition projects at the INEEL are also buried in the SDA. Low-level waste from offsite generators includes biological wastes, laboratory wastes, and other items contaminated with radioactive material.

Low-level waste is classified by its handling requirements as CH-LLW or RH-LLW. Remote-handled LLW has exposure rates above 500 mR/h at 1 m from the waste package surface. Remote-handled LLW was buried in pits, trenches, and soil vaults. Trenches received high-radiation waste until trench disposal was discontinued in 1981. Soil vault disposals were conducted until 1995. Remote-handled LLW is currently disposed of in the active pits and concrete vaults located in the active pits.

The TRU drum inventories in Table 3-6 do not include the fission and activation products because:

- Most fission and activation products are not contained in the same drums and boxes as TRU
- Most activation products are expected to be in discrete RH-LLW packages buried in the trenches and vaults.
- Most fission products are probably in resins or nuclear fuel-related material that would be discrete from activation products or TRU packages.

The direct radiation information is used to estimate the maximum quantity of LLW activation products in a single package. If the 24,000 R/hr source term were entirely Co-60, the Co-60 content would be 17,500 Ci, without taking credit for decay. This inventory would be bounding for the pits and trenches. Packages in the soil vaults have not been characterized, but are expected to be similar.

Table 3-7 shows information on best-estimate LLW inventories in the SDA. The isotopes in Table 3-7 are the fission and activation products that comprise at least 1% of the total inventory. Some radionuclides, such as antimony, iodine, krypton, cadmium, lead, and mercury are not included because of their lower inventory and relatively low inhalation hazard.

Table 3-7. Estimated inventory for significant LLW radionuclides at the SDA.

Isotope	Total Best-Estimate Inventory (Ci)	Best-Estimate Average Inventory (Ci/ ft^2)	Total Limiting Inventory (Ci)	Limiting Average Inventory (Ci/ ft^2)
Co-60	2.2E+06	1.8E+00	9.4E+06	2.4E+01
Fe-55	4.0E+06	3.3E+00	6.3E+06	1.6E+01
Cr-51	7.8E+05	6.4E-01	4.8E+06	1.2E+01
H-3	1.5E+06	1.2E+00	3.8E+06	9.7E+00
Ni-63	1.3E+06	1.1E+00	2.2E+06	5.7E+00
Co-58	3.6E+05	3.0E-01	1.7E+06	4.4E+00
Mn-54	3.0E+05	2.5E-01	1.4E+06	3.6E+00
Sr-90	6.4E+05	5.3E-01	1.3E+06	3.3E+00
Cs-137	6.2E+05	5.1E-01	9.6E+05	2.5E+00
Ce-144	1.5E+05	1.2E-01	5.2E+05	1.3E+00

As with the transuranics, ISTD pretreatment will have little affect on the LLW inventories.

3.3.2.1.3.5 Nonradioactive Inventory—The RWMC contains large quantities of nonradioactive contaminants. Table 3-8 lists the nonradioactive contaminants in the SDA ordered alphabetically. Updated best-estimate values for carbon tetrachloride, tetrachloroethylene, trichloroethylene, and 1,1,1-trichloroethane are from Varvel.[7]

The most abundant and hazardous contaminants are sodium and potassium nitrates; organics, particularly carbon tetrachloride; and metals such as lead, beryllium, and zirconium. The nitrates (primarily 745 sludge) resulted from evaporation of high nitrate waste in ponds at RFP. Because of the landfill disposal methods used during the 1960s, potassium or sodium nitrates were dumped into the same area as organic materials. A mixture of nitrates and organics may be potentially explosive.[13]

Most of the organic chemicals found in RFP wastes are from organic setups. Organic setups (primarily 743 sludge) were produced from treatment of liquid organic wastes generated by various plutonium and nonplutonium operations at the RFP. The organic wastes were mixed with calcium silicate to form a grease or paste-like material. Small amounts of Oil Dri (trade name) absorbent were usually mixed with the waste. Studies have been performed to determine the maximum quantity of carbon tetrachloride that could be present in a 743-sludge drum.[14] These studies show that carbon tetrachloride quantity could be as high as 128 kg (20.9 gal). Thus, for work specifically involving 743-sludge drums, this is considered to be the bounding quantity of carbon tetrachloride.

Large quantities of zirconium and zirconium alloy that are technically considered a combustible metal are buried at the SDA, but the combustibility of zirconium decreases as the average particle size increases. As large bars, narrow plates, and long strips, zirconium can withstand extremely high temperatures without igniting. Spontaneous ignition or explosions of zirconium during handling are not likely unless the metal is very finely divided. Beryllium (although not pyrophoric) when in dust or flake form and mixed with carbon tetrachloride, trichloroethane, or trichloroethylene will form flammable gases that can spark or flash. As large blocks, beryllium is not likely to form flammable gases.

There is no evidence that ordnance or explicit explosives were buried at the SDA. However, oxidizers in the form of nitrates and dichromates, which can be explosive when mixed with oils, are present in the pits. There is little evidence that pyrophoric metals are buried at the SDA in a form that would either spontaneously ignite or would be easily ignited and self-sustaining.

Based on experience with the stored waste inventory, hydrogen gas may be present because of radiological decomposition in wastes containing water or organic materials. Hydrogen gas will disperse over time through poly bags; however, it could be contained in sealed drums that are still in good condition. It is believed that most of the metal drums will have corroded over 36 years of burial or were damaged during disposal to the point that they could not contain hydrogen gas. However, there is a remote possibility that some have maintained their integrity and could contain ignitable concentrations of hydrogen gas.

In situ thermal desorption pretreatment will significantly reduce the nonradioactive hazardous material inventory of the treated areas, since it is specifically intended to destroy these materials. Table 3-9 describes the chemical composition and behavior of the four waste types that will be treated using ISTD. The resulting products will be removed by the heater/vacuum wells and treated by the off-gas treatment system during ISTD processing and before ISG.

Few hazardous byproducts are expected from the ISTD process. Those produced will be driven off with the ISTD off-gasses and treated in the off-gas system; thus, significant quantities of hazardous ISTD byproducts in the ground after treatment are not expected.[1]

Table 3-8. Nonradioactive hazardous material inventory.

Contaminant	Upper-bound Inventory (g)	Best Estimate Inventory Density (g/drum)	Best Estimate Inventory Density (g/ft^2)	Limiting Inventory Density (g/drum)	Limiting Inventory Density (g/ft^2)
1,1,1-trichloroethane	1.2E+08	3.2E+02	1.7E+02	3.9E+04	1.4E+04
1,1,2-trichloro-1,2,2-trifluoroethane	9.5E+06	2.5E+01	1.3E+01	3.1E+03	1.1E+03
2-butanone	4.0E+04	1.1E-01	5.6E-02	1.3E+01	4.6E+00
Acetone	1.3E+05	3.4E-01	1.8E-01	4.2E+01	1.5E+01
Aluminum nitrate nonahydrate	2.4E+08	6.4E+02	3.4E+02	7.7E+04	2.7E+04
Ammonia	1.8E+06	4.8E+00	2.5E+00	5.8E+02	2.1E+02
Anthracene	4.6E+02	1.2E-03	6.5E-04	1.5E-01	5.3E-02
Antimony	1.0E+03	2.7E-03	1.4E-03	3.2E-01	1.1E-01
Aqua regia	3.2E+01	8.5E-05	4.5E-05	1.0E-02	3.7E-03
Arsenic	1.1E+00	3.0E-06	1.6E-06	3.6E-04	1.3E-04
Asbestos	4.8E+06	1.3E+01	6.7E+00	1.5E+03	5.5E+02
Barium	1.2E+01	3.2E-05	1.7E-05	3.9E-03	1.4E-03
Benzine	4.8E+03	1.3E-02	6.7E-03	1.5E+00	5.5E-01
Beryllium	7.3E+07	1.9E+02	1.0E+02	2.4E+04	8.4E+03
Butyl alcohol	1.1E+05	2.9E-01	1.5E-01	3.5E+01	1.3E+01
Cadmium	2.3E+06	6.1E+00	3.2E+00	7.4E+02	2.6E+02
Carbon tetrachloride	8.2E+08	2.2E+03	1.2E+03	2.6E+05	9.4E+04
Cerium chloride	6.2E+05	1.6E+00	8.7E-01	2.0E+02	7.1E+01
Chloroform	3.7E+01	9.8E-05	5.2E-05	1.2E-02	4.2E-03
Chromium	1.6E+03	4.2E-03	2.2E-03	5.1E-01	1.8E-01
Copper	4.5E+04	1.2E-01	6.3E-02	1.5E+01	5.2E+00
Copper nitrate	4.1E+02	1.1E-03	5.8E-04	1.3E-01	4.7E-02
Ethyl alcohol	2.8E+04	7.4E-02	3.9E-02	9.0E+00	3.2E+00
Formaldehyde	1.5E+05	4.0E-01	2.1E-01	4.8E+01	1.7E+01
Hydrazine	2.3E+03	6.1E-03	3.2E-03	7.4E-01	2.6E-01
Hydrofluoric acid	9.4E+06	2.5E+01	1.3E+01	3.0E+03	1.1E+03
Lead	7.8E+08	2.1E+03	1.1E+03	2.5E+05	8.9E+04
Magnesium	1.1E+07	2.9E+01	1.5E+01	3.5E+03	1.3E+03
Magnesium fluoride	1.4E+05	3.7E-01	2.0E-01	4.5E+01	1.6E+01
Mercury	2.0E+06	5.2E+00	2.7E+00	7.1E+03	2.5E+03
Mercury nitrate monohydrate	1.0E+06	2.7E+00	1.4E+00	3.2E+02	1.1E+02
Methyl alcohol	2.5E+05	6.6E-01	3.5E-01	8.0E+01	2.9E+01
Methyl isobutyl ketone	1.1E+07	2.9E+01	1.5E+01	3.5E+03	1.3E+03
Methylene chloride	1.5E+07	4.0E+01	2.1E+01	4.8E+03	1.7E+03
Nickel	4.1E+03	1.1E-02	5.8E-03	1.3E+00	4.7E-01

Table 3-8. (continued).

Contaminant	Upper-bound Inventory (g)	Best Estimate Inventory Density		Limiting Inventory Density	
		(g/drum)	(g/ft^2)	(g/drum)	(g/ft^2)
Nitric acid	6.1E+07	1.6E+02	8.6E+01	2.0E+04	7.0E+03
Potassium chloride	9.1E+07	2.4E+02	1.3E+02	2.9E+04	1.0E+04
Potassium dichromate	3.0E+06	8.0E+00	4.2E+00	9.6E+02	3.4E+02
Potassium nitrate	2.4E+09	6.4E+03	3.4E+03	7.7E+05	2.7E+05
Potassium phosphate	1.3E+07	3.4E+01	1.8E+01	4.2E+03	1.5E+03
Potassium sulfate	9.1E+07	2.4E+02	1.3E+02	2.9E+04	1.0E+04
Silver	7.3E+03	1.9E-02	1.0E-02	2.3E+00	8.4E-01
Sodium	7.5E+04	2.0E-01	1.1E-01	2.4E+01	8.6E+00
Sodium chloride	1.8E+08	4.8E+02	2.5E+02	5.8E+04	2.1E+04
Sodium cyanide	1.9E+03	5.0E-03	2.7E-03	6.1E-01	2.2E-01
Sodium dichromate	5.4E+06	1.4E+01	7.6E+00	1.7E+03	6.2E+02
Sodium hydroxide	3.4E+02	9.0E-04	4.8E-04	1.1E-01	3.9E-02
Sodium nitrate	4.6E+09	1.2E+04	6.5E+03	1.5E+06	5.3E+05
Sodium phosphate	2.7E+07	7.2E+01	3.8E+01	8.7E+03	3.1E+03
Sodium potassium	2.3E+06	6.1E+00	3.2E+00	7.4E+02	2.6E+02
Sodium sulfate	2.1E+08	5.6E+02	2.9E+02	6.7E+04	2.4E+04
Sulfuric acid	1.5E+05	4.0E-01	2.1E-01	4.8E+01	1.7E+01
Terphenyl	1.0E+06	2.7E+00	1.4E+00	3.2E+02	1.1E+02
Tetrachloroethylene	9.8E+07	2.6E+02	1.4E+02	3.1E+04	1.1E+04
Toluene	2.5E+05	6.6E-01	3.5E-01	8.0E+01	2.9E+01
Tributyl phosphate	1.3E+06	3.4E+00	1.8E+00	4.2E+02	1.5E+02
Trichloroethylene	1.2E+08	3.2E+02	1.7E+02	3.9E+04	1.4E+04
Trimethylolpropane-triester	1.6E+06	4.2E+00	2.2E+00	5.1E+02	1.8E+02
Uranium	5.4E+08	1.4E+03	7.6E+02	1.7E+05	6.2E+04
Uranyl nitrate	2.8E+05	7.4E-01	3.9E-01	9.0E+01	3.2E+01
Versenes (EDTA)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Xylene	9.8E+05	2.6E+00	1.4E+00	3.1E+02	1.1E+02
Zirconium	2.3E+07	6.1E+01	3.2E+01	7.4E+03	2.6E+03
Zirconium alloys	7.3E+06	1.9E+01	1.0E+01	2.3E+03	8.4E+02
Zirconium oxide	5.3E+03	1.4E-02	7.4E-03	1.7E+00	6.1E-01

Table 3-9. Nonradioactive hazardous materials destroyed by ISTD treatment.

Waste Type	Compounds	What Happens During ISTD	Resulting Products to Off-gas Treatment System
Organic (743 Sludge)	Carbon Tetrachloride, Tetrachloroethylene (PCE), Trichloroethylene (TCE), Trichloroethane (TCA), Texaco Regal Oil (TRO), Miscellaneous oils, Freon, Polyethylene	All compounds are destroyed.	Water Vapor, Carbon Dioxide, Hydrogen Chloride, Hydrogen Fluoride, Oxides, Nitrogen, Chlorides
Nitrate (745 Sludge)	Sodium Nitrate, Potassium Nitrate, Sodium Sulfate, Sodium Chloride, Polyethylene	Sodium Nitrate, Potassium Nitrate, and Sodium Sulfate decompose, leaving respective oxides. Sodium Chloride does not decompose at ISTD temperatures.	Nitrogen dioxide, Sulfur trioxide, Oxygen, Water Vapor, Carbon Dioxide
Combustible Solids	Cellulose, polyvinyl chloride (PVC), Polyethylene	All compounds are destroyed.	Water Vapor, Carbon Dioxide, Hydrogen Chloride
Graphite	Carbon, Polyethylene	All compounds are destroyed.	Water Vapor, Carbon Dioxide

3.3.2.1.3.6 Hazard Categorization—The RWMC SDA had been designated as a Hazard Category 2 facility. Since this work is being performed in the SDA and involves intrusion into the waste, this activity is Hazard Category 2.

3.3.2.1.3.7 Hazard Evaluation—For the hazards identified in Section 3.3.2.1, all the hazards determined to be significant or not routinely encountered are analyzed further. The hazards evaluated are:

- High-pressure mechanical components
- Criticality from fissile material
- Direct radiation
- Radioactive materials and nonradioactive hazardous chemicals
- Fire and explosion
- Natural phenomena
- External events.

3.3.2.1.4 Hazard Table—The evaluation of these hazards is presented in Table 3-10. The qualitative unmitigated likelihood and consequences of an event are shown. Risk-binning is performed, based on the criteria in Section 3.3.1.2.

The nonradioactive material consequences in Table 3-10 assume that the full inventory of nonradioactive hazardous materials are present with no pretreatment. Potential effects of ISTD pretreatment include the following:

- TRU and other radionuclides may be concentrated in the heater/vacuum well sand filters and the well header piping; however, there is no strong mechanism for this to occur. The wells and well header piping will be grouted and buried after ISTD.

- TRU and other radionuclides may accumulate at the boundaries of subsurface voids created or enlarged by ISTD.

- The potential for subsidence will be increased by the larger void spaces created by ISTD. This effect will be offset by the 10-ft soil cover that will be placed over the ISTD treatment area and the additional cover added to bury the wells and well header piping.

- The potential for underground explosions, deflagrations or fires will be significantly reduced because nitrates, hydrogen, and other combustible materials will be destroyed by ISTD. Also, the additional soil overburden will both prevent and mitigate these events.

- The nonradioactive material consequences of release events will be significantly reduced because volatile organics and other hazardous materials will be destroyed by ISTD.

Table 3-10 also lists mitigating design and administrative barriers. When warranted by the risk bin, SS SSCs and TSRs are identified in bold italics.

Each of the hazardous events and initiators/causes in Table 3-10 is discussed in the following paragraphs. The alphanumeric identifiers provide the cross-reference to Table 3-10.

The following define items in Table 3-10:

1. High-pressure Mechanical Components and Grout

   1.a.i) The high-pressure grouting system operates at high pressure (expected to be approximately 6,000 psi). A similar system failed during a test program at the INEEL, generating a projectile that injured a worker. This accident is a similar failure. No radioactive or hazardous material is contained in the grouting system, so none would be released if the system fails. Although this is a nonnuclear industrial hazard, it is unique to the grouting activity and is not adequately addressed by existing programs. Because of the very high pressure, this is not a standard industrial hazard. A failure could generate a projectile or release high-pressure grout with sufficient energy to cause a fatality. Following the guidance of DOE-ID Order 420.D, a system that can produce a fatal accident is moderate hazard. The INEEL accident investigation recommended design improvements to prevent such an accident. These will be incorporated into the MCS design.

2. Criticality

   2.a.i) Criticality events are addressed in greater detail in Chapter 6 and are included here for completeness. Criticality is not a credible event for ISG activities as determined in Section 6.3. The first postulated event is a criticality resulting from injecting cementitious grout. The safety evaluation shows this event is beyond extremely unlikely. Consequences are judged to be low because the plutonium is underground and thus the ground would shield the radiation produced by a criticality. There are no concerns about criticality in the early action areas because there are insignificant quantities of fissile material.

Table 3-10. Hazards evaluation of in situ grouting at the Subsurface Disposal Area.

Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood, Consequence, and Risk Without Controls[a]				Preventive and Mitigative Features	
				Likelihood Category	Consequence Category		Risk Bin #	Design[b]	Administrative[c]
1. High pressure mechanical components and grout (Nonnuclear industrial hazard)	a. High pressure grouting system fails generating a projectile or releasing high-pressure grout.	i). Failure of high pressure grouting equipment	High pressure grouting equipment	Anticipated	Off-Site Public: Co-located Workers: Facility Workers: Environment: (Categorized per DOE-ID Order 420.D)	N N M N	NA NA NA —	***ISG study high-pressure safety system recommendations***[15]	Quality assurance program. Configuration management.
2. Fissile material (No fissile material in early action area)	a. Inadvertent criticality associated with waste	i). Cementitious grout injection adds moderator or rearranges fissile material to create criticality.	Buried TRU waste at grout injection location.	Beyond Extremely Unlikely	Off-Site Public: Co-located Workers: Facility Workers: Environment:	N N L N	1 1 3 —	See Chapter 6	See Chapter 6
		ii). Paraffin grout injection adds moderator or rearranges fissile material to create a criticality	Buried TRU waste at grout injection location.	Extremely Unlikely	Off-Site Public: Co-located Workers: Facility Workers: Environment:	N N L N	2 2 5 —	See Chapter 6	See Chapter 6
3. Direct radiation	a. Excess worker exposure from RH-LLW	i). Installing or moving the MCS uncovers a buried high radiation component exposing workers to high radiation.	SDA pits, trenches and soil vaults	Unlikely	Off-Site Public: Co-located Workers: Facility Workers: Environment:	N N M N	4 4 ***12*** —	Soil cover. MCS track sized to minimize soil disturbance.	***SDA grouting & maintenance procedures. Radiation Protection Program***.
		ii). A subsidence event occurs that results in uncovering RH-LLW and exposing workers.	SDA pits, trenches and soil vaults.	Unlikely	Off-Site Public: Co-located Workers: Facility Workers: Environment:	N N M N	4 4 ***12*** —	Soil cover MCS track sized to prevent subsidence MCS designed to withstand subsidence event.	***SDA maintenance procedures. Radiation Protection Program***.

Table 3-10. (continued).

Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood, Consequence, and Risk Without Controls[a] Likelihood Category	Consequence Category		Risk Bin #	Preventive and Mitigative Features Design[b]	Administrative[c]
4. Radioactive and nonradioactive hazardous materials	a. Excess exposure from airborne materials	i). Installing or moving the MCS removes the soil resulting in airborne hazardous materials.	SDA pits and trenches	Anticipated	Radiological Off-Site Public: Co-located Worker s: Facility Workers: Environment: Nonradioactive Off-Site Public: Co-located Workers: Facility Workers: Environment:	N N L L N N L N	7 7 11 — 7 7 11 —	Soil cover MCS vehicle track sized to minimize soil disturbance.	Operating procedures. Radiation Protection Program.
		ii). Subsidence uncovers waste resulting in airborne hazardous materials.	SDA pits and trenches	Anticipated	Radiological Off-Site Public: Co-located Workers: Facility Workers: Environment: Nonradioactive Off-Site Public: Co-located Workers: Facility Workers: Environment:	N N L L N N L N	7 7 11 — 7 7 11 —	Soil cover MCS vehicle track sized to prevent subsidence.	Operating procedures. Radiation Protection Program.

Table 3-10. (continued).

				Likelihood, Consequence, and Risk Without Controls[a]				Preventive and Mitigative Features	
Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood Category	Consequence Category		Risk Bin #	Design[b]	Administrative[c]
		iii). Drill penetrates a drum containing hydrogen causing a hydrogen explosion that expels hazardous material to the surface. Anticipate few drums could produce or contain hydrogen in early action areas.	SDA pits and trenches	Extremely Unlikely[16]	Radiological Off-Site Public: Co-located Workers: Facility Workers: Environment: Nonradioactive Off-Site Public: Co-located Workers: Facility Workers: Environment:	 N L M L N L M N	 2 5 9 — 2 5 9 —	Soil cover MCS operating gallery and maintenance glovebox.	Radiation Protection Program. Prevent access to MCS operating area during grouting. Emergency Preparedness Program.
		iv). Drill penetrates pressurized gas cylinder that expels hazardous material to the surface.	SDA pits and trenches	Extremely Unlikely[16]	Radiological Off-Site Public: Co-located Workers: Facility Workers: Environment: Nonradioactive Off-Site Public: Co-located Workers: Facility Workers: Environment:	 N L M L N L M N	 2 5 9 — 2 5 9 —	Soil cover MCS operating gallery and maintenance glovebox.	Radiation Protection Program. Prevent access to MCS operating area during grouting. Emergency Preparedness Program.

Table 3-10. (continued).

Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood, Consequence, and Risk Without Controls[a]: Likelihood Category	Consequence Category		Risk Bin #	Preventive and Mitigative Features: Design[b]	Administrative[c]
		v). Combustible or flammable waste materials, including methane from microbial action, pyrophorics, or nitrate/organics are ignited by drilling and hazardous materials are driven to the surface.	SDA pits and trenches	Extremely Unlikely[16]	Radiological Off-Site Public: Co-located Workers: Facility Workers: Environment: Nonradioactive Off-Site Public: Co-located Workers: Facility Workers: Environment:	 N L M L N L M N	 2 5 9 — 2 5 9 —	Soil cover MCS operating gallery and maintenance glovebox.	Emergency Preparedness Program Prevent access to MCS operating area during grouting.
		vi). Leak in the drill string shroud or filter failure releases hazardous material.	Area around the drill rig in the MCS.	Anticipated	Radiological Off-Site Public: Co-located Workers: Facility Workers: Environment: Nonradioactive Off-Site Public: Co-located Workers: Facility Workers: Environment:	 N N N N N N N L	 7 7 7 — 7 7 7 —	Contaminants are in the grout. Drill string shroud. MCS.	Procedures and training Maintenance program.

Table 3-10. (continued).

				Likelihood, Consequence, and Risk Without Controls[a]				Preventive and Mitigative Features	
Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood Category	Consequence Category		Risk Bin #	Design[b]	Administrative[c]
		vii). Grout returns bring high content of hazardous materials to the surface.	Newly grouted area under the MCS	Unlikely	Radiological Off-Site Public: Co-located Workers: Facility Workers: Environment: Nonradioactive Off-Site Public: Co-located Workers: Facility Workers: Environment:	 N N L N N N L N	 4 4 8 — 4 4 8 —	Contaminates are in the grout. Drill string shroud. MCS.	Procedures and training. Radiation Protection Program. Prevent access to MCS operating area during grouting. Industrial Hygiene Program.
		viii).Failure of the MCS structure, sealing system, or ventilation system filters.	MCS	Anticipated	Radiological Off-Site Public: Co-located Workers: Facility Workers: Environment: Nonradioactive Off-Site Public: Co-located Workers: Facility Workers: Environment:	 N N L N N N L L	 7 7 11 — 7 7 11 —	MCS is a secondary containment.	Maintenance Program

Table 3-10. (continued).

Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood, Consequence, and Risk Without Controls[a]				Preventive and Mitigative Features	
				Likelihood Category	Consequence Category		Risk Bin #	Design[b]	Administrative[c]
		ix). Grout returns come to surface beyond the area covered by the MCS.	Area adjacent to the MCS	Anticipated	Radiological Off-Site Public: Co-located Workers: Facility Workers: Environment: Nonradioactive Off-Site Public: Co-located Workers: Facility Workers: Environment:	 N N L N N N L L	 7 7 11 — 7 7 11 —	Contaminants are in the grout. MCS coverage extends beyond immediate grouting area.	Procedures and training. Radiation Protection Program.
5. Fire/explosion	a. Fire on the drill rig	i). Electrical panel failure, paraffin grout fire, or fuel leak causes a fire on the drill rig.	On the drill rig within the MCS.	Anticipated	Off-Site Public: Co-located Workers: Facility Workers: Environment:	N N N N	7 7 7 —	Waste beneath soil cover will not be exposed.	Prevent access to MCS operating area during grouting. Fire protection program. Emergency Preparedness Program.
	b. Fire in the MCS.	i). Electrical failure, paraffin grout fire, or fuel leak causes a fire in the MCS.	MCS.	Anticipated	Off-Site Public: Co-located Workers: Facility Workers: Environment:	N N N N	7 7 7 —	Waste beneath soil cover will not be exposed.	Prevent access to MCS operating area during grouting. Fire protection program. Emergency Preparedness Program.

Table 3-10. (continued).

Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood, Consequence, and Risk Without Controls[a]				Preventive and Mitigative Features	
				Likelihood Category	Consequence Category		Risk Bin #	Design[b]	Administrative[c]
	c. Underground fire.	i). Paraffin grout is ignited underground by drilling bit or an ignition source in the waste.	SDA pits and trenches	Extremely Unlikely	Off-Site Public: Co-located Workers: Facility Workers: Environment:	N N L L	2 2 5 —	Soil cover MCS.	Fire protection program Emergency Preparedness Program.
6. Natural phenomena	a. Flood	i). Flooding from surface water runoff, flooding bodies of water near the RWMC, and/or Mackay Dam failure.	SDA area currently being grouted.	Unlikely	Off-Site Public: Co-located Workers: Facility Workers: Environment:	N N N N	See foot note[d]	SDA flood control design.	Procedures for maintenance and inspection of culverts, dikes, and drainage channels. Emergency Preparedness Program.
	b. Lightning	i). Lightning strikes the MCS or drill rig.	MCS and/or drill rig.	Anticipated	Off-Site Public: Co-located Workers: Facility Workers: Environment:	N N N N	See foot note[d]	Drill rig and MCS have lightning protection.	Fire protection program, procedures and training. Emergency Preparedness Program.
	c. Volcano	i). Lava flow encroaches on the area being grouted.	SDA area, currently being grouted, including the MCS and rill rig.	Extremely Unlikely	Off-Site Public: Co-located Workers: Facility Workers: Environment:	N N N N	See foot note[d]	Waste beneath soil cover will not be exposed.	Advance notice would provide time to secure facility and evacuate. Emergency Preparedness Program.

Table 3-10. (continued).

Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood, Consequence, and Risk Without Controls[a]				Preventive and Mitigative Features	
				Likelihood Category	Consequence Category		Risk Bin #	Design[b]	Administrative[c]
	d. Earthquake	i). Earthquake disrupts the drill rig, compromises the MCS, and/or creates a subsidence.	SDA area currently being grouted, including the MCS and drill rig.	Unlikely	Off-Site Public: Co-located Workers: Facility Workers: Environment:	N N L N	See footnote[d]	MCS and drill rig designed to seismic standards. Soil cover.	SDA maintenance procedures. Operating procedures and training. Radiation Protection Program.
	e. High wind or tornado	i). High wind may damage the MCS or affect the drill rig.	MCS and drill rig.	Unlikely	Off-Site Public: Co-located Workers: Facility Workers: Environment:	N N N N	See footnote[d]	MCS designed to AE standards. Waste beneath soil cover will not be exposed.	Grouting terminated during high winds. Operating procedures and training.
	f. Snow load	i). High snow loading compromises the MCS.	MCS.	Unlikely	Off-Site Public: Co-located Workers: Facility Workers: Environment:	N N N N	See footnote[d]	MCS designed to AE standards. Waste beneath soil cover will not be exposed.	Maintenance removes excessive snow. Operating procedures and training.
7. Hazards from external events	a. Loss of electrical power	i). Offsite power is disrupted from an undefined cause.	Drilling rig and MCS ventilation system.	Anticipated	Off-Site Public: Co-located Workers: Facility Workers: Environment:	N N N N	7 7 7 —	Electrical system design. Emergency power supply.	
	b. Range fire	i). Range fire involves the MCS.	Drilling rig and MCS.	Unlikely	Off-Site Public: Co-located Workers: Facility Workers: Environment:	N N L N	4 4 8 —	Waste beneath soil cover will not be exposed.	Fire protection program. Emergency Preparedness Program.

Table 3-10. (continued).

				Likelihood, Consequence, and Risk Without Controls[a]				Preventive and Mitigative Features	
Hazard	Hazardous Event	Initiator/Cause	Applicable Facilities or Functions	Likelihood Category	Consequence Category		Risk Bin #	Design[b]	Administrative[c]
	c. Aircraft crash into the MCS.	i). Aircraft crashes into the MCS.	MCS and rill rig.	Beyond Extremely Unlikely	Off-Site Public: Co-located Workers: Facility Workers: Environment:	N N M N	1 1 6 —		Fire protection program.

a. Additional explanation of Likelihood and Consequence Categories and the Risk Bin Numbers is provided in 3.3.1.
b. SSCs designated as safety-class or safety-significant SSCs are highlighted in ***bold italics***.
c. TSR level controls are highlighted in ***bold italics.***
d. Natural phenomena hazard initiated events are not assigned a risk bin number. See discussion for each of the natural phenomena hazards in the text of Section 3.3.2.3.

2.a.ii) Paraffin grout is an organic material that can act as a moderator of neutrons. Thus, the paraffin grout is more susceptible to causing a criticality, although it is still considered extremely unlikely. If it occurred, the criticality would be in the grouted waste under the ground where the consequences to a facility worker would be low. To maintain the criticality margin, paraffin grouting is not anticipated at this time for the TRU pits and trenches. If it is used in association with TRU waste, boron must be added to the paraffin as a neutron poison. There are no concerns about criticality in the early action areas, because there are insignificant quantities of fissile material.

3. Direct Radiation

3.a.i) The SDA contains items with direct radiation levels up to 24,000 R/hr that are shielded by the soil cover. Moving or installing the MCS over the soil cover creates a potential to accidentally remove the soil cover, exposing workers to radiation levels that could produce doses in the moderate consequence category.

3.a.ii) Subsidence has been a common occurrence at the SDA. None of the subsidence events have exposed high-radiation components. However, grouting activities such as surface preparation, moving the MCS, and injecting the grout may create the potential for more severe subsidence that exposes highly radioactive materials. Although minor subsidence is anticipated, more severe subsidence that exposes buried components is unlikely. Areas containing high radiation components are not planned for ISTD pretreatment, so pretreatment will not affect this accident.

4. Radioactive and Nonradioactive Hazardous Materials

4.a.i) Large quantities of radioactive and nonradioactive hazardous materials are buried in the SDA. Surface preparation, and moving and installing the MCS, create a potential for airborne contamination. The airborne quantity is expected to be small because there is no significant driver mechanism, so the dose consequences are rated as low.

4.a.ii) Subsidence has been a common occurrence at the SDA. None of the subsidence events have created significant airborne activity. However, grouting activities such as moving the MCS and injecting grout may create the potential for more severe subsidence that creates airborne activity. The airborne quantity is expected to be small because there is no significant driver mechanism, so the dose consequences are rated low.

In situ thermal desorption pretreatment may increase the likelihood of subsidence by creating large voids under the surface; however, since this event is already categorized as "anticipated," pretreatment will not increase the likelihood category. The radiological consequences will remain the same, but pretreatment will reduce or eliminate the nonradioactive material consequences.

4.a.iii) Some of the buried drums contain materials that have generated hydrogen within the drums. Although this is uncommon and most of the drums are so degraded they could not contain hydrogen, there is still a potential to drill into a buried drum containing hydrogen and produce an explosion. The explosion is assumed to drive contamination into the containment system and then outside the containment with no mitigating credit for the containment system filters. The probability is extremely unlikely.[16] The consequence for a worker in the containment would be moderate; for the collocated worker, low; and for the offsite public, negligible. This accident is probably not a concern in the early action areas because there are no drums that could produce or contain hydrogen buried there. In situ thermal desorption pretreatment should reduce the probability and consequence of this event by further degrading drums that could contain hydrogen and by destroying the hydrogen.

4.a.iv) Pressurized gas cylinders may be buried in the SDA. Drilling into a pressurized gas cylinder could produce a driving force that would create airborne contamination. The consequences are expected to be similar to a hydrogen explosion.

4.a.v) There is a variety of materials buried in the SDA that are combustible, flammable, or explosive. These include common materials such as paper, wood, and organic liquids. They could also be produced through chemical interactions such as nitrates acting with organics or methane resulting from microbial action. There may also be pyrophoric materials. The potential for an accident created by these materials has been extensively studied. [16,17] These studies show the event is extremely unlikely. The consequences would be moderate, similar to a hydrogen explosion. The probability for such an event is lower in the early action areas. In situ thermal desorption pretreatment will reduce the probability and consequence of this event by destroying combustible, flammable, and explosive materials in the pretreated areas.4.a.vi) The drill penetrates the buried waste and is then withdrawn during the routing process. This cycle creates the potential for the drill string to bring quantities of hazardous material to the surface where they can become airborne. Most of the hazardous material will be retained in the grout. Also, the drill may be refused and return to the surface without grout, but carrying contamination. The drill string shroud is provided to prevent spread of contamination, but the enclosure may fail. This is an anticipated event. But the quantity of hazardous material will be small and mixed with grout if it is present on the drill surface, so the consequences will be negligible.

4.a.vii) During normal grouting, some grout returns up through the soil to the surface. These materials are called "grout returns" and may contain hazardous material. There is a potential for unusually large quantities of hazardous material to be brought to the surface through this pathway. Because the contamination level is unusually large, the event probability is unlikely. Exposure to a worker in the containment is projected to be moderate. In situ thermal desorption pretreatment will reduce the probability and consequence of this event by destroying combustible, flammable, and explosive materials in the pretreated areas.

4.a.viii) The MCS is provided to prevent the spread of contamination that may be brought to the surface. The only normal pathways are in the grout returns and on the drill string. The MCS may fail to perform its function, either through worker entry, failure of the ventilation filters, failure of the seal between the containment and the ground, or by a failure of the structure itself. This is an anticipated event. Because the hazardous materials will be largely contained within the grout, the consequences to a facility worker are expected to be low.

4.a.ix) There is a potential for the grout returns to come to the surface outside the MCS. The consequences of this event are the same as those for a failure of the MCS to contain contamination. Because the hazardous materials will be largely contained within the grout, the consequences to a facility worker are expected to be low. In situ thermal desorption pretreatment will reduce the probability and consequence of this event by destroying combustible, flammable, and explosive materials in the pretreated areas.

5. Fire/explosion

5.a.i) An electrical panel failure, paraffin grout fire, or fuel leak could cause a fire on the drill rig. This type of initiator is anticipated. The only radioactive or hazardous contamination that would be involved is the small amount on the drill stem. Although some equipment would be damaged, there would be little hazard from spread of contamination or direct radiation. Therefore, the consequences are negligible.

5.b.i) An electrical failure, paraffin grout fire, or fuel leak could also cause a fire that damages the MCS. Because most of the hazardous material is buried, the only hazardous material potentially involved is in the grout returns and on the drilling equipment. This is a small source term confined by the grout, so the consequences to a facility worker are negligible.

5.c.i) If paraffin-based grout is used, the grout material itself is combustible. This creates the potential for an underground fire involving injected grout. The grout will be heated above its melting temperature of 125°F for injection in the ground. The flash point of one proposed paraffin-based grout is 455°F. The only mechanisms that could ignite the grout are friction from the drill bit or fire involving one of the combustible, flammable, or explosive waste materials. This event is extremely unlikely. Energy absorbing properties and containment capability of the soil in which the material is buried would keep the consequences low.

6. Natural Phenomena

6.a.i) Floods are discussed in Chapter 3 of the RWMC SAR. A flood could inundate the area involved in grouting, but should not affect the buried material. The amount of hazardous material involved would be small and would be retained in the grout. Because the waste remains buried during grouting, and because there were no consequences from previous floods, the consequences would be negligible.

6.b.i) A lightning strike could damage the drilling equipment or the containment and might trigger a fire as discussed above. However, the lightning should have little affect on the buried waste or hazardous material brought to the surface on the drilling equipment or in the grout returns. The equipment and containment will have lightning protection.

6.c.i) Volcanic activity has occurred in the recent geologic past and could occur again. A lava flow is extremely unlikely (See Chapter 1 of SAR-100). The MCS and drilling equipment could be destroyed, but because the waste remains buried, grouting does not make the waste susceptible to volcanic activity and the consequences would be negligible.

6.d.i) An earthquake could damage the drilling equipment and MCS. An earthquake could also create subsidence that would expose waste in the area being grouted. Consequences of the subsidence would be similar to those for the subsidence event discussed, including exposure to high levels of direct radiation. The drilling equipment and MCS will be designed to the appropriate performance category seismic design criteria.

6.e.i) High wind or tornado could damage the drilling equipment and MCS, but would have little affect on the waste being grouted. Thus the consequences are expected to be negligible.

6.f.i) High snow loading could damage the drilling equipment and MCS, but would little affect on the waste being grouted. Thus the consequences are expected to be negligible.

7. Hazards from external events

7.a.i) Loss of electrical power would result in terminating drilling activities and shutting down the ventilation system for the MCS; however, this would have no affect on the waste being grouted and would not result in the release of any activity.

7.b.i) A range fire would be unlikely to penetrate into the SDA and reach the grouting activity. If it did, the waste would remain beneath the surface or enclosed in the grout returns. The airborne contents of the containment could be released, producing low consequences to the facility worker and negligible consequences downwind.

7.c.i) An aircraft crash would destroy the MCS and drilling equipment. It could also penetrate the soil cover and unearth quantities of buried waste. However, grouting will not exacerbate the affects of an airplane crash, which is considered a beyond extremely unlikely event.

Nearby facilities with hazards that could affect SDA grouting include the Advanced Mixed Waste Treatment Facility, Transuranic Storage Area, and other parts of the SDA, which are all at the RWMC; other INEEL facilities; and offsite facilities. All these facilities are sufficiently isolated from SDA grouting that an event at these facilities will not trigger further events at the SDA grouting facility. The risk to workers at SDA grouting from other facilities is the airborne spread of radioactive or nonradioactive hazardous substances. The frequency and consequence depend on the specific accident. Any event releasing such materials would trigger the emergency notification system and appropriate actions would be taken to protect workers.

3.3.2.1.4.1 Planned Design and Operational Safety Improvements—The grouting system is designated as a Safety Significant System, Structure, or Component (SS SSC). It will be designed to incorporate operational safety and protect workers from the hazards of high pressure grouting. The system will include the following items that were recommended following a high-pressure grouting system failure at the RWMC:[15]

- A high-pressure relief valve and redundant pressure relief plug system
- Pressure gauges that operate smoothly at all pressures
- Pressure-rated equipment and fittings such as valves, hoses, and tie-downs
- Plugging-resistant nozzles.

The MCS will have the following design features to enhance safety:

- MCS is designed to prevent contamination from spreading
- The MCS track design will limit soil disturbance and subsidence
- Workers will not be permitted inside the MCS during grouting operations
- The operating gallery and maintenance glovebox reduce the need to enter the MCS operating area
- The MCS will be sealed while being moved between setups.

3.3.2.1.4.2 Defense-in-Depth—The defense-in-depth approach builds in levels of safety so no one level by itself, no matter how good, is completely relied upon. Defense-in-depth is used as a best management practice; no safety class items are required. The first level of safety is administrative controls or the design of process equipment to ensure that hazards are safely contained. The second level is alarms and detection systems that enable shutdown of the event before an accident initiates. The third level is mitigation, such as final containment, filtered ventilation exhaust, or evacuation, provided in the event that the first two levels have failed and the accident has progressed to a state of damage and release of material.

Each of the three levels of the defense-in-depth approach to overall safety applies to fissile material, ionizing radiation, radioactive material, hazardous chemicals, external events, and natural phenomena hazards. The intent is to identify the broad purpose and importance of defense-in-depth features, not the details of their design or implementation. Table 3-11 broadly identifies these features.

Table 3-11. Defense-in-depth features.

Hazard	First Level	Second Level	Third Level
Criticality	Waste acceptance, procedures, criticality safety evaluation, training	Not required	Emergency response/evacuation
Radioactive materials/hazardous chemical exposure	Facility/equipment design, Radiation Protection Program, minimum staffing, procedures, training	Alarms/detection, fire protection system	Emergency response/evacuation
Fire	Fire protection program, procedures, training	Fire suppression system, alarms	Emergency response/evacuation
Explosion	Facility design, fire protection program, procedures, training	Fire suppression system	Emergency response/evacuation
Natural phenomena	Building design, training	Monitoring environmental conditions (such as weather and seismic)	Emergency response

The soil cover is the first barrier to release of hazardous materials during normal operation. Only small quantities of hazardous materials will be brought to the surface through the drill string and grout returns, and these will be mixed with the grout and not susceptible to release. Use of the drill shroud and

MCS provide defense-in-depth. The drill shroud and grouting MCS provide multiple barriers to protect against spreading contamination during normal operations and potential accidents.

3.3.2.1.4.3 Safety Significant SSCs—As required by DOE-STD 3009-94, part of the defense-in-depth is to identify those SSCs that are safety significant. The only SS SSC for grouting is listed in Table 3-12 where it is designated as passive or active.

Table 3-12. Safety significant SSCs for ISG.

Hazard	SSC	Passive Active
Projectiles and high-pressure grout	High-pressure grouting system	Active

3.3.2.1.4.4 Technical Safety Requirements—This section summarizes those safety-significant SSCs and other aspects of defense-in-depth that will be provided technical safety requirement coverage. Features designated for TSR coverage are listed in Table 3-13.

Table 3-13. Hazard protection features requiring TSR coverage.

Hazard	Major Protection Features	TSR
Projectiles and high pressure grout	Relief valves and plug, gauges, equipment and fittings, and plug resistance nozzles	Verify operability and condition of protection features.
Direct radiation	Procedures to prevent, recognize, and respond to subsidence	Existing TSR requirement for procedures and training

A TSR requiring a radiation protection program is not included because this program is required by 10 CFR 835, Occupational Radiation Protection.[18] The radiation protection program will ensure procedures will be instituted so workers will not be permitted inside the MCS during grouting operations and will control access for maintenance and other activities. The MCS design minimizes the need to enter the MCS by providing the operating gallery and maintenance glovebox. The radiation protection program will also ensure the soil cover is maintained to protect workers from radiation exposure.

3.3.2.1.4.5 Worker Safety—The INEEL's Integrated Safety Management System (ISMS) ensures that safety is considered in all aspects of operations and maintenance, and is fully integrated into planning and performing work processes. Workers will be trained on the specific hazards of ISG that are identified in this document. Procedures will include discussion of the hazards and the proper response to mitigate the hazard and prevent injury.

3.3.2.1.4.6 Environmental Protection—Use of the HEPA-filtered containment ensures there will be no unregulated releases of hazardous materials during normal operation of the system. Also, placing a clean layer of grout over the soil cover after the waste is grouted, followed by capping and applying a fixative, helps to prevent the spread of any contamination.

3.3.2.1.4.7 Accident Selection—The hazard evaluation in Table 3-10 shows the highest hazards are from projectiles or high-pressure grout generated by pressurized grouting system failure, and from direct radiation or airborne contamination resulting from uncovering the waste or from an explosion in the waste. No further accident analysis is needed to demonstrate that the high pressure grouting system should be designated as an SS SSC. A detailed accident analysis will be performed to assess the hazards from failure of the MCS, uncovering high radiation sources, and from an explosion in the waste.

3.4 Accident Analysis

This section analyzes the accidents selected in Section 3.3 through the hazard analysis process. These are bounding accidents that will be used to establish the safety controls. Consequences from events anywhere in the entire SDA and in the early action areas only will be considered for each accident. The early action areas are pits 7, 8, 13–16, trenches 16–58, and soil vault rows 1–21. The effects of ISTD pretreatment will also be discussed.

In accordance with direction in DOE-STD-3009-94, exposures to the facility workers from accidental releases have been qualitatively assessed and equipment that is safety significant to facility workers has been determined in Table 3-10.

3.4.1 Methodology

The source term for the accidents evaluated in this document that release hazardous material were calculated using the following source term equation recommended by DOE-STD-3010-94, Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities:

$$ST = MAR \times DR \times ARF \times RF \times LPF. \qquad (1)$$

where:

ST = source term (Ci)

MAR = material at risk (Ci)

DR = damage ratio

ARF = airborne release fraction

RF = respirable fraction

LPF = leak path factor.

Material at risk: Information about the quantities of radioactive materials buried in the SDA is in Section 3.3.2.1.3. The material at risk for a particular accident is a subset of the entire inventory that is determined based on the nature of the accident and the intent of the analysis. The MAR for each accident is determined in the appropriate section.

Damage ratio: The damage ratio (DR) is the fraction of the MAR that could be affected by the postulated accident and is a function of the accident initiator and the operation event being evaluated. The DR for each accident is discussed in the appropriate section.

Airborne release fraction: The airborne release fraction (ARF) is the coefficient used to estimate the amount of a radioactive material suspended in air and made available for airborne transport. The ARF for each accident is taken from the applicable bounding values presented in DOE-STD-3010-94 and is discussed in the appropriate section.

Respirable fraction: The respirable fraction (RF) is the fraction of airborne radionuclides as particles that can be transported through air and inhaled into the human respiratory system. It is commonly assumed to include particles of 10 μm aerodynamic equivalent diameter or less. The RFs are taken from the applicable bounding values presented in DOE-STD-3010-94 and are discussed in the appropriate section.

Leak path factor: The leak path factor (LPF) is the fraction of radionuclides transported through some enclosure.

The Radiological Safety Analysis Computer Program (RSAC)-6[19] is used to quantify the downwind radiological consequences of postulated accidents. The meteorological model in RSAC-6 calculates Gaussian plume diffusion using Pasquill-Gifford, Hilsmeier-Gifford, or Markee diffusion factors. The Markee and Hilsmeier-Gifford models are used to simulate releases over desert terrains. The Markee model is used to simulate releases whose duration is from 15 to 60 minutes, while the Hilsmeier-Gifford model is used to simulate releases whose duration is from a few minutes to 15 minutes.

Downwind concentrations from release of the nonradioactive contaminants are calculated using the equation:

$$CONC = (ST/t) * \chi/Q. \qquad (2)$$

where:

CONC	=	downwind concentration
ST	=	Quantity released to the environment
t	=	release time
χ/Q	=	Atmospheric diffusion factor. The (χ/Q) values are calculated by RSAC-6 for the appropriate diffusion conditions and distances.

The accident consequences for grouting were evaluated in EDF-3418[20] and EDF-3563[21] using the methods described above.

The radiological and hazardous chemical risk evaluation guidelines (EGs) used for this analysis are listed in Table 3-14.

Table 3-14. Risk evaluation guidelines.

Event/Accident Likelihood/Frequency	On-Site Worker Consequences	Off-Site Public Consequences
Anticipated (1E-01 to 1E-02/yr)		
Radiological	5.0 rem (TEDE)[a]	0.5 rem (TEDE)[a]
Nonradioactive	ERPG-1 or equivalent[b]	TLV-TWA[c]
Unlikely (1E-02 to 1E-04/yr)		
Radiological	25 rem (TEDE)	5.0 rem (TEDE)
Nonradioactive	ERPG-2 or equivalent	ERPG-1or equivalent
Extremely Unlikely (1E-04 to 1E-06/yr)		
Radiological	100 rem (TEDE)[d]	25 rem (TEDE)
Nonradioactive	ERPG-3 or equivalent[d]	ERPG-2 or equivalent

a. "TEDE" = Total Effective Dose Equivalent
b. "ERPG" = Emergency Response Planning Guide (American Industrial Hygiene Association) "Equivalent" means a concentration of a hazardous chemical causing potential health effects similar to ERPG-1 levels, but for which an ERPG-1 concentration has not been established (e.g., TLV ceiling level). Likewise, "equivalent" to ERPG-2 and ERPG-3 mean concentrations of hazardous chemicals causing potential health effects similar to ERPG-2/3 levels, but for which ERPG-2/3 concentrations have not been established.
c. "TLV-TWA" = Threshold Limit Value - Time-Weighted Average
d. These guidelines apply only to workers in a neighboring facility, not in-facility workers.

3.4.2 Design Basis Accidents

3.4.2.1 DBA-1—Failure of the MCS During Grouting

3.4.2.1.1 Scenario Development—In this scenario, grouting operations are being conducted in a normal manner when the MCS fails and its contents are released to the environment. The MCS could fail from a variety of environmental causes, such as wind damage, flooding, or excessive snow loading. Also, the building structure could be impacted by another object such as a vehicle or falling equipment. The ventilation filtration system could fail, resulting in direct ventilation releases to the environment. Failure of the MCS is an anticipated event. This event is evaluated for a best-estimate inventory and a limiting inventory. Failure involving the best-estimate inventory is anticipated and failure involving the limiting inventory is unlikely.

3.4.2.1.2 Source Term Analysis—The source term for this potential accident is the radioactive and nonradioactive hazardous constituents that become airborne in the MCS after being brought to the surface on the drill stem and in the grout returns. Grout returns are the quantities of grout that return to the surface after being injected into the ground.

In situ grouting treatability studies[15] were performed at the RWMC to assess the performance of the grouting process. The treatability studies involved injecting grout into a trench that contained buried waste materials similar to those in the RWMC. The treatability studies used a thrust block for containment instead of the MCS. Rather than having the drill string enclosed in the containment, the drill string penetrated the thrust block. Terbium was added to the buried waste as a plutonium analog to assess how plutonium might migrate during RWMC grouting. The study showed that terbium was present in very low concentrations on the top of the thrust block drill hole and on the inside surface of the inner drill shroud. The treatability study did not provide sufficient information to make quantitative estimates of plutonium migration; however, it showed that plutonium and other contaminants could be brought to the surface by the drill string and the grout returns.

To provide a conservative assessment, it is assumed the accident occurs at a time when the maximum quantity of grout returns is under the MCS. It also does not take credit for the clean grout and fixative that will be placed over the grout returns. Based on experience with grouting studies,[15] half the treated ground volume under the MCS will be waste.

The MAR for this accident is the hazardous material in the waste being grouted under the MCS. This waste is estimated to be under an area 15 × 15 ft square. The MAR quantities for TRU, non-TRU, and nonradioactive hazardous contaminants are determined in EDF-3418 and shown in Tables 3-15 and 3-17 for the best-estimate inventory, and Tables 3-16 and 3-18 for the limiting inventory.

The DR is the fraction of MAR that is available for release in the grout returns. The waste containers are breached, so the grout will contact the waste; however, the grout will enclose the waste rather than intimately mix with it. Therefore, it is conservatively estimated that 25% of the hazardous material in the waste will be mixed with the grout. The volume of grout returns brought to the surface is estimated to be 88 ft^3. As the grout dries, the hazardous constituents will be retained in the grout. The grout will become a dry solid that limits the resuspension of material. It is therefore estimated that resuspension will occur in the top surface to a depth of 100 μm. Based on these considerations, the damage ratio is 1.05 E-05. Solid nonradioactive hazardous metals are expected to remain intact as the grout flows around the waste package. For these metals, 1% is estimated to leave the grout and the DR is reduced to 4.19 E-07.

The ARF is the percentage of hazardous material in the grout returns that becomes airborne in the MCS. The ARF is 5 E-03 from DOE-HDBK-3010-94.[22] It is assumed that volatile nonradioactive hazardous contaminants will not be retained in the top 100 μm of grout returns. For these materials, the ARF is 1.0.

Following DOE STD-3010-94, the RF is assumed to be 0.3, except for volatile materials where it is 1.0.

The LPF is assumed to be 1.0 because the airborne contamination is assumed to escape through a breach or failed filter.

The ST resulting from these calculations is shown in Tables 3-15 and 3-17 for the anticipated category, and Tables 3-16 and 3-18 for the unlikely category.

For grouting in the early action areas, the source term is modified in two ways.

Early action will only be performed in non-TRU areas, so it is assumed there are no TRU nuclides, including Pu-239, in the source term.

Some of the nonradioactive hazardous contaminants were only buried in the TRU areas. These are also excluded from the early action area source terms: carbon tetrachloride, potassium chloride, potassium dichromate, potassium nitrate, potassium phosphate, potassium sulfate, sodium dichromate, sodium nitrate, and trichloroethylene.

In areas pretreated with ISTD, the pretreatment will have no effect on the radioactive source term, so Tables 3-15 and 3-16 will not change; however, ISTD pretreatment will have destroyed much of the nonradioactive hazardous material. At least 50% of the carbon tetrachloride and other chlorinated hydrocarbons, and up to 80 % of the nitrates, will be destroyed in the pretreated areas.[23] Additional volatile hydrocarbons will be driven off with the ISTD off-gas and destroyed in the off-gas treatment system; thus, the quantity of carbon tetrachloride and other volatile organics in the ground will be reduced by at least 50%, and possibly up to 100%. The values in Tables 3-17 and 3-18 will be reduced accordingly. The sodium nitrate will be reduced by up to 80%.

Table 3-15. Radiological consequences for anticipated MCS failure accident.

Nuclide	Best-Estimate MAR (Ci)	Best-Estimate Release (Ci)	TEDE at 100 m (Rem)	TEDE at 3 km (Rem)	TEDE at 6 km (Rem)
Pu-239	2.32E+02	3.65E-06	1.70E-02	6.30E-05	2.30E-05
Co-60	4.10E+02	6.46E-06	1.52E-05	5.70E-08	2.09E-08
Fe-55	7.40E+02	1.17E-05	3.36E-07	1.25E-09	4.59E-10
Cr-51	1.40E+02	2.21E-06	8.38E-09	3.13E-11	1.14E-11
H-3	2.70E+02	4.25E-06	0.00E+00	0.00E+00	0.00E+00
Ni-63	2.50E+02	3.94E-06	9.73E-08	3.63E-10	1.33E-10
Co-58	6.80E+01	1.07E-06	1.32E-07	4.94E-10	1.81E-10
Mn-54	5.60E+01	8.82E-07	6.84E-08	2.56E-10	9.35E-11
Sr-90	1.20E+02	1.89E-06	2.63E-05	9.83E-08	3.61E-08
Cs-137	1.20E+02	1.89E-06	6.46E-07	2.42E-09	8.86E-10
Ce-144	2.70E+01	4.25E-07	1.70E-06	6.38E-09	2.33E-09
Total			1.70E-02	6.3E-05	2.3E-05
Non-TRU Total			4.45E-05	1.66E-07	6.11E-08

Note: Collocated worker is at 100 m and offsite receptors at 3 km and 6 km.

Table 3-16. Radiological consequences for unlikely MCS failure accident.

Nuclide	Limiting MAR (Ci)	Limiting Release (Ci)	TEDE at 100 m (Rem)	TEDE at 3 km (Rem)	TEDE at 6 km (Rem)
Pu-239	2.63E+02	4.14 E–06	1.90 E-02	7.2 E-05	2.6 E-05
Co-60	5.40E+03	2.23E-05	2.01E-04	7.50E-07	2.75E-07
Fe-55	3.60E+03	1.49E-05	1.63E-06	6.07E-09	2.23E-09
Cr-51	2.70E+03	1.11E-05	1.62E-07	6.04E-10	2.21E-10
H-3	2.20E+03	9.08E-06	0.00E+00	0.00E+00	0.00E+00
Ni-63	1.30E+03	5.36E-06	5.06E-07	1.89E-09	6.92E-10
Co-58	9.90E+02	4.08E-06	1.92E-06	7.19E-09	2.64E-09
Mn-54	8.10E+02	3.34E-06	9.90E-07	3.70E-09	1.35E-09
Sr-90	7.40E+02	3.05E-06	1.62E-04	6.06E-07	2.23E-07
Cs-137	5.60E+02	2.31E-06	3.02E-06	1.13E-08	4.14E-09
Ce-144	2.90E+02	1.20E-06	1.83E-05	6.85E-08	2.50E-08
Total			1.94 E-02	7.3 E-05	2.7 E-05
Non-TRU Total			3.89E-04	1.46E-06	5.34E-07

Note: Collocated worker is at 100 m and offsite receptors at 3 km and 6 km.

Table 3-17. Nonradioactive hazardous material concentrations for the anticipated MCS failure accident.

Contaminant	Best Estimate MAR (gms)	Best Estimate ST (gms)	100 m Conc (mg/m^3)	Collocated Worker EG [a]	3 km Conc (mg/m^3)	6 km Conc (mg/m^3)	Offsite Receptor EG [b] (mg/m^3)
Beryllium	2.25E+04	1.41E-05	7.58E-07	0.005	2.83E-09	1.04E-09	0.002
Carbon Tetrachloride	2.70E+5	2.84E+1	1.52E-01	128	5.68E-04	2.08E-04	31.46
Hydrofluoric Acid	2.93E+03	3.08E-02	1.65E-03	1.5	6.16E-06	2.26E-06	1.5
Nitric acid	1.94E+04	2.04E-01	1.09E-02	3	4.08E-05	1.50E-05	2.5
Sodium nitrate	1.46E+06	2.37E-02	1.27E-03	1	4.61E-06	1.69E-06	0.4
Uranium	1.71E+05	2.69E-03	1.44E-04	0.6	5.40E-07	1.98E-07	0.05

a. For collocated worker at 100 m, evaluation guideline value is ERPG-1.
b. For offsite receptors at 3 km and 6 km, evaluation guideline value is TLV-TWA or TEEL-0.

Table 3-18. Nonradioactive hazardous concentrations for the unlikely MCS failure accident.

	Limiting MAR (gms)	Limiting ST (gms)	100 m Conc (mg/m^3)	Collocated Worker EG [a]	3 km Conc (mg/m^3)	6 km Conc (mg/m^3)	Offsite Receptor EG[b] (mg/m^3)
Beryllium	1.89E+06	1.19E-03	6.37E-05	0.025	2.38E-07	8.72E-08	0.005
Carbon Tetrachloride	1.06E+07	1.11E+02	5.97E+00	639	2.23E-02	8.17E-03	128
Hydrofluoric Acid	2.48E+05	2.60E+00	1.40E-01	16.4	5.22E-04	1.91E-04	1.5
Nitric acid	1.58E+06	1.66E+01	8.90E-01	15	3.32E-03	1.22E-03	3
Sodium nitrate	1.19E+08	1.87E+00	1.00E-01	7.5	3.75E-04	1.38E-04	1
Uranium	1.40E+07	2.21E-01	1.18E-02	1.0	4.42E-05	1.62E-05	0.6

a. For collocated worker at 100 m, guideline value is ERPG-2/TEEL-2.
b. For offsite receptors at 3 km and 6 km, guideline value is ERPG-1/TEEL-1.

3.4.2.1.3 Consequence Analysis—Downwind accident consequences for a short time release of the calculate source term are shown at distances of 100 m (collocated worker), 3 km (EBR-1), and 6 km (nearest site boundary). Hilsmeier-Gifford meteorological diffusion conditions were used because they were developed for desert terrains and releases from a few to 15 minutes. Table 3-15 shows the consequences for the anticipated accident, and table 3-16 for the unlikely accident.

Radiological consequences for grouting in the early action areas will be those for the non-TRU radionuclides only. These are also shown in Tables 3-15 and 3-16.

For ISTD pretreated areas, the radiological consequences will be the same as those shown in Tables 3-15 and 3-16.

The quantity of nonradioactive hazardous contaminants from Table 3-8 that would be released in the anticipated accident were determined in EDF-3418. The six contaminants that most closely approached their evaluation guidelines are shown in Table 3-17. Disposal information shows that hydrofluoric acid and nitric acid are no longer present as volatile acids in the SDA. Both were disposed of in the acid pit and neutralized with lime.[20] The quantity of nonradioactive hazardous contaminants from Table 3-8 that would be released in the unlikely accident is also determined in EDF-3418. The six contaminants that most closely approached their evaluation guidelines are shown in Table 3-18.

The same calculations apply to the early action areas, except, as discussed above, there is no carbon tetrachloride and sodium nitrate.

For ISTD pretreated areas, in Tables 3-17 and 3-18 the carbon tetrachloride concentration will be reduced by at least 50% and possibly up to 100%.The sodium nitrate will be reduced by up to 80%.

3.4.2.1.4 Comparison to Guidelines—For the anticipated accident, the downwind consequences for the collocated worker and offsite person are well below the guidelines values of 5 Rem and ERPG-1 for the collocated worker and 0.5 Rem and TLV-TWA for the offsite receptor.

For the early action areas, where there is no TRU source term, the radiological consequences are all well below guideline values. Nonradioactive hazardous materials all produce concentrations well below the ERPG-1 or TEEL-1 values.

For the anticipated accident in ISTD pretreated areas, the downwind consequences for the collocated worker and offsite person are well below the guidelines values of 5 Rem and ERPG-1 for the collocated worker and 0.5 Rem and TLV-TWA for the offsite receptor.

For the unlikely accident, the downwind radiological dose rates and nonradioactive hazardous material concentrations to the collocated worker and offsite receptors remain below the evaluation guidelines.

For the unlikely accident in the early action areas, where there is no TRU source term, the radiological dose rates and nonradioactive hazardous materials concentrations are all well below guideline values.

For the unlikely accident in the pretreated areas, the downwind radiological dose rates and nonradioactive hazardous material concentrations to the collocated worker and offsite receptors remain below the evaluation guidelines.

3.4.2.1.5 Summary of Safety Significant SSCS and TSR Controls—Because the radiological and nonradioactive hazardous material consequences for this accident are all below their guideline values, no TSR or SS SSCS are required.

3.4.2.2 DBA-2—Uncovering a High Radiation Source

3.4.2.2.1 Scenario Development—This scenario assumes a high radiation source buried in the SDA is uncovered and exposes workers to direct gamma radiation emanating from the buried object. This event could occur anywhere in the SDA and thus the consequences for the entire SDA and the early action areas are the same. Table 3-10 identifies two mechanisms that could uncover such an object: accidentally removing soil cover that is too thin while preparing the surface, installing or moving the MCS vehicle, or initiating subsidence by moving the MCS vehicle. This event is "unlikely."

3.4.2.2.2 Source Term Analysis—The source term for such an event is the radiation emanating from the buried object. As discussed in Section 3.3.2.1.3, the upper bound radiation package is 24,000 R/hr. This source is appropriate for the extremely unlikely category.

This analysis is for uncovering a package with a source of 1000 R/hr. There were 17 out of 861 RH LLW packages that exceeded 1000 R/hr when they were buried. Such an exposure level is judged to be consistent with a probability category of unlikely.

3.4.2.2.3 Consequence Analysis—It is assumed that the high-radiation object is inadvertently uncovered so the radiation shines directly to the environment in the immediate area, and that work continues in that area for a period of time before the radiation field is discovered. The radiation field is attenuated with the square of the distance. For a source term of 1000 R/hr at 2 ft, the exposure rate is 40 R/hr at 10 ft from the source. Thus, a facility worker 10 ft from the source would receive a dose of 5 Rem in 7 minutes, 25 Rem in 37 minutes. The consequence category for the unlikely direct radiation exposure accident is moderate. Doses to collocated workers at 100 m, or offsite individuals at 3 or 6 km, would be negligible because of their distances from the source.

For the extremely unlikely case, the 24,000 R/hr source at 2 ft has an exposure rate at 10 ft of 960 R/hr. A worker 10 ft from the source would receive a dose of 25 Rem in less than 2 minutes.

3.4.2.2.4 Comparison To Guidelines—As shown in Figure 3-3, with a probability category of either "anticipated" or "unlikely," a dose of 25 Rem is the threshold for establishing SS SSCs or TSR controls for the facility worker. The consequences of this accident are sufficient to require safety significant SSCs and/or TSR controls.

3.4.2.2.5 Summary Of SS SSCS And TSR Controls—The primary means of protecting against direct radiation is maintaining the soil cover. This is currently done using the existing radiation protection program, and would continue to be done the same way for ISG. The radiation protection program would require verifying the soil cover depth before placing the drilling/grouting equipment and would require procedures to inspect and monitor soil cover integrity during movements and grouting operation to prevent removing the overburden. Workers would also be trained on the need to prevent subsidence and to leave the area and report subsidence events.

3.4.2.3 DBA-3—Grouting Initiated Buried Waste Explosion

3.4.2.3.1 Scenario Development—Flammable and potentially explosive materials are buried in the RWMC's SDA. The presence of these substances raises concern about the potential for fires and explosions. This section evaluates the consequences of an explosion. It is assumed the drill penetrates a waste drum initiating an explosion within a drum containing flammable or explosive materials.

Because of this concern, an independent technical review was performed to assess these hazards for drilling activities supporting the OU 7-10 project.[16] The review panel's conclusions also apply to ISG drilling in the SDA. The panel reviewed six scenarios, which are repeated in Table 3-19.

Table 3-19. Buried waste explosion scenarios.

Scenario	Description	Evaluation
1. Drilling into a mixture of nitrate salts and hydrocarbon oils.	Drums containing sodium and potassium nitrates, hydrocarbon oils, and chlorinated solvents were disposed. The potential for the drill to encounter a mixture of nitrates and combustible organics does exist.	Explosion beyond extremely unlikely if $H_2O > 5$ wt%. Explosion extremely unlikely if $H_2O < 5$ wt%. Fire extremely unlikely.
2. Drilling into a mixture of nitrate salts and graphite.	Graphite (mainly in the form of chunks and large pieces) was also placed into drums and disposed. There is the potential for the sonic drill to encounter a mixture of nitrate salts and graphite.	Explosion beyond extremely unlikely Fire extremely unlikely.
3. Drilling into a mixture of nitrate salts and cellulose (wood/paper).	Large quantities of wood and paperboard containers were disposed permitting the possible encounter of nitrate salts and cellulose-based materials.	Explosion beyond extremely unlikely if drill bit <150°C. Fire extremely unlikely.

Table 3-19. (continued)

Scenario	Description	Evaluation
4. Drilling into an intact drum containing hydrogen.	Hydrogen can be produced through radiolytic decomposition of organic materials. There is the potential for the production of hydrogen and other gases.	Explosion extremely unlikely. Fire extremely unlikely.
5. Drilling into potentially pyrophoric or reactive materials, e.g., zirconium and depleted uranium; containers of picric acid, and lithium batteries.	There is documentation and, in some cases, concerns that these materials were placed in the SDA.	Explosion extremely unlikely. Fire extremely unlikely.
6. Drilling into pressurized cylinders containing a flammable gas.	While no documentation exists that supports the disposal of pressurized gas cylinders, this possibility was considered to be credible.	Explosion extremely unlikely. Fire extremely unlikely.

The explosion could be from any of the scenarios shown in Table 3-19. It is further assumed that the soil cover has inadvertently degraded so the cover is ineffective in completely containing the contents of the drum. To evaluate the consequences without the effect of mitigative features, it is also assumed the MCS is not functioning.

Such an accident involves the compounding of several unlikely conditions. Nitrates and combustibles would be intermingled with the soil, which inhibits forming an explosive mixture. Most of the drums are breached, so they cannot contain radiolytically-generated hydrogen, which would dissipate into the soil. The soil cover would normally be in place, thus containing and limiting the effects of any reaction.

A single drum is assumed to explode and expel its hazardous contents upward through a breach in the soil cover. A single drum is considered because the drill would only impact a single drum at one time. Other drums would be further beneath the ground surface. As shown in Table 3-19, a single drum explosion is extremely unlikely. The potential to deflagrate nearby drums is less probable, thus becoming beyond extremely unlikely. It is assumed the contents reach the MCS atmosphere where they are transported downwind, exposing collocated workers and offsite members of the public.

3.4.2.3.2 Source Term Analysis. The radioactive and nonradioactive hazardous material source terms are determined in EDF-3563. The source term is developed for a single drum. However, results of this analysis can be applied to an explosion with a larger number of drum equivalents by multiplying the consequences reported for this scenario by the number of drum equivalents. Guidance presented in EDF-3543, Table 5, says to use a drum filled with either Pu-239-eq or Am-241, but not both. To maximize the receptor dose, the inventory is calculated for a single drum containing Am-241.

Anticipated, unlikely, and extremely unlikely hazardous material inventories have been developed. Because an explosion is extremely unlikely, the anticipated inventory is appropriate for an overall event probability of extremely unlikely. The overall event likelihood for an extremely unlikely explosion combined with an unlikely or extremely unlikely inventory is beyond extremely unlikely. Thus, the following analysis is for the extremely unlikely scenario and assumes an anticipated inventory.

The damage ratio is based on the results of drum explosion tests while the airborne release factors and respirable factors are from DOE-HDBK-3010-94 for venting of pressurized volumes. The airborne release fraction could be reduced for the activation products in the inventory, since the radionuclides would be expected to reside in solid metal objects. However, to be conservative, the airborne release fraction is not reduced for activation products.

The existing overburden provides some filtration of the radioactive material. An explosion would be expected to loosen but not completely expel the overburden above the explosion location. The assumption is based on the fact that upper drums would have approximately 3 ft of soil cover while the average depth of drums would be on the order of 10 ft. From these observations, the soil is assumed to behave as a granular bed filter. Based on an analysis of granular bed filters,[24] 10 cm (4 in.) of overburden gives a leak path factor of 0.1. DOE STD-3009-94 allows the unmitigated analysis to "take credit for passive safety features that are assessed to survive accident conditions where that capability is necessary in order to define a physically meaningful scenario."

For the nonradioactive hazardous material source term, nonvolatile chemicals are treated as radionuclides per DOE-HDBK-3010-94. Volatile chemicals are conservatively assumed to be completely released to the atmosphere.

The asbestos, beryllium, cadmium, and lead in the SDA are considered to be in large pieces and not dispersible. The MAR for asbestos, beryllium, cadmium, and lead is set to zero. The heat of the explosion might generate phosgene and hydrochloric acid. The analysis assumes that 10% of the chlorinated hydrocarbons decompose to hydrochloric acid, and 1% of the halogenated compounds convert to phosgene gas with a molecular conversion ratio of 1.19.[25] To implement the assumption, the quantity of hydrochloric acid is calculated by multiplying the sum of the release rate for the chlorinated hydrocarbons (1,1,1-trichloroethane, 1,1,2-trichloro-1,2,2-trifluoroethane, methylene chloride, tetrachloroethylene, trichloroethylene) by 0.1 while the quantity of phosgene is calculated by multiplying the sum of the release rate for the halogenated compounds (1,1,1-trichloroethane, 1,1,2-trichloro-1,2,2-trifluoroethane, carbon tetrachloride, chloroform, methylene chloride, tetrachloroethylene, and trichloroethylene) by 0.0119.

The resulting radioactive source terms are listed in Table 3-20. The release rate of the ten nonradioactive hazardous materials with the largest ratio of concentration to the evaluation guideline for the receptor at 6 km are listed in Table 3-21.

Table 3-20 also applies to the early action areas, except there is no Am-241 or Pu-239. Some of the nonradioactive hazardous contaminants were only buried in the TRU areas. Those not present in the early action area source terms areas are carbon tetrachloride, potassium nitrate, sodium nitrate, and trichloroethylene.

In areas pretreated with ISTD, treatment is predicted to destroy up to 80% of the nitrates. It would also destroy many of the other materials that could contribute to an underground drum explosion; thus, in these areas, the probability of a drum explosion would decrease to beyond extremely unlikely. The pretreatment will have no affect on the radiological source term, so Table 3-20 will not change; however, at least 50% (and possibly up to 100%) of the carbon tetrachloride and other chlorinated hydrocarbons, and up to 80 % of the nitrates, will be destroyed in the pretreated areas.[23] Thus, in Table 3-21, the phosgene, hydrochloric acid, carbon tetrachloride, trichloroethylene, tetrachloroethylene, 1,1,1-trichloroethane, and methylene chloride source terms will be reduced by at least 50%, and the sodium nitrate by up to 80%.

Table 3-20. Nonradioactive hazardous material source term and downwind concentrations for the underground drum explosion.

Material	MAR (Ci)	ST (Ci)	TEDE at 100 m (Rem)	TEDE at 3 km (Rem)	TEDE at 6 km (Rem)
Am-241	7.4E-01	4.9E-05	2.3E–01	8.8E–04	3.2E–04
Co-60	1.3E+01	8.4E-04	2.0E–03	7.4E–06	2.7E–06
Fe-55	2.3E+01	1.5E-03	4.4E–05	1.6E–07	6.1E–08
Cr-51	4.5E+00	3.0E-04	1.1E–06	4.2E–09	1.6E–09
H-3	8.4E+00	5.6E-04	0.0E+00	0.0E+00	0.0E+00
Ni-63	7.7E+00	5.1E-04	1.3E–05	4.7E–08	1.7E–08
Co-58	2.1E+00	1.4E-04	1.7E–05	6.5E–08	2.4E–08
Mn-54	1.8E+00	1.2E-04	9.1E–06	3.4E–08	1.2E–08
Sr-90	3.7E+00	2.5E-04	3.4E–03	1.3E–05	4.7E–06
Cs-137	3.6E+00	2.4E-04	8.1E–05	3.0E–07	1.1E–07
Ce-144	8.4E-01	5.6E-05	2.2E–04	8.4E–07	3.1E–07
Total			2.4E-01	9.0E-04	3.3E-04
Total Non-TRU (early action areas)			5.8E-03	2.2E-05	7.9E-06
Evaluation Guideline (extremely unlikely)			100	25	25

Table 3-21. Nonradioactive hazardous material source term and downwind concentrations for the underground drum explosion.

Material	Release Rate (mg/s)	Conc at 100 m (mg/m^3)	ERPG-3 (mg/m^3)	Conc at 3 km (mg/m^3)	Conc at 6 km (mg/m^3)	ERPG-2 (mg/m^3)
Phosgene	1.4E+01	4.5E-01	4	1.7E-03	6.1E-04	0.8
Hydrochloric Acid	3.6E+01	1.1E+00	224	4.3E-03	1.6E-03	30
Carbon tetrachloride	8.1E+02	2.6E+01	4,790	9.8E-02	3.6E-02	639
Sodium nitrate	2.2E+00	7.1E-02	100	2.7E-04	9.8E-05	7.5
Uranium	2.2E-01	7.2E-03	10	2.7E-05	9.8E-06	1
Potassium nitrate	1.2E+00	3.8E-02	500	1.4E-04	5.2E-05	20
Trichloroethylene	1.2E+02	3.8E+00	26,900	1.4E-02	5.2E-03	2,690
Tetrachloroethylene	9.6E+01	3.1E+00	6890	1.2E-02	4.2E-03	1,378
1,1,1-trichloroethane	1.2E+02	3.8E+00	19,250	1.4E-02	5.2E-03	3,850
Methylene chloride	1.5E+01	4.8E-01	13,920	1.8E-03	6.5E-04	2,610

***3.4.2.3.3 Consequence Analysis*—**The dose and concentration consequences from the drum explosion are calculated using the Hilsmeier-Gifford dispersion model with 15-minute release duration. Results are shown in Table 3-20 for radioactive materials and Table 3-21 for nonradioactive hazardous materials.

Table 3-20 also shows the radiological doses for the early action scenario, except there is no Am-241. In Table 3-21, the nonradioactive hazardous materials carbon tetrachloride, potassium chloride, potassium dichromate, potassium nitrate, potassium phosphate, potassium sulfate, sodium dichromate, sodium nitrate, and trichloroethylene will not be present in the early action areas.

For ISTD pretreated areas, Table 3-20 shows the radiological doses. In Table 3-21, the nonradioactive hazardous materials phosgene, hydrochloric acid, carbon tetrachloride, trichloroethylene, tetrachloroethylene, 1,1,1-trichloroethane, and methylene chloride concentrations will be reduced by at least 50%, and the sodium nitrate by up to 80%.

3.4.2.3.4 Comparison To The Evaluation Guideline—The radiological dose consequences from the drum explosion scenario are compared to the extremely unlikely evaluation guidelines in Table 3-20. No guidelines are exceeded.

Table 3-21 shows the concentrations of the ten nonradioactive materials with the largest ratio of concentration to the evaluation guideline for the receptor at 6 km. The evaluation guideline for the collocated worker at 100 m is the ERPG-3 value. The evaluation guideline for an offsite member of the public at 3 km or 6 km is the ERPG-2 value. No concentrations at 100 m, 3 km, or 6 km exceed the evaluation guidelines.

3.4.2.3.5 Summary of Safety-Class SSCS and TSR Controls—No safety class or SS SSCs are required for this accident.

3.4.3 Beyond Design Basis Accidents

Beyond design basis accidents would be those whose probability is lower than extremely unlikely and with consequences more severe than the design basis accidents. Accidents with lower probability include those involving a drum with radionuclide or nonradioactive hazardous material contents higher than those used for the analysis. Boxes could also contain more hazardous materials.

Another severe accident would be an underground explosion triggered by grouting that involves many drums and a large volume of waste. The consequences of such an event could be very severe, depending on the quantity of material released. However, there is no credible initiating event that could cause such an explosion.

Higher drum content or multiple drum release would produce dose consequences proportionately higher.

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4. SAFETY STRUCTURES, SYSTEMS, AND COMPONENTS

4.1 Introduction

This chapter provides details on facility structures, systems, and components (SSCs) that are necessary for the facility to satisfy evaluation guidelines, provide defense in depth, or contribute to worker safety. The attributes required to support the safety functions identified in the hazard and accident analyses and support subsequent derivation of TSRs are described.

4.2 Requirements

The following codes, standards, regulations, and DOE Orders are specific to this section and pertinent to the safety assessment:

- 10 CFR 830, Subpart A, Quality Assurance Requirements
- 10 CFR 830, Subpart B, Safety Basis Requirements
- DOE Order 420.1A, Facility Safety
- DOE-ID Order 420.D, Requirements and Guidance for Safety Analysis
- DOE-STD-3009-94, Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses
- DOE-ID, *Architectural Engineering Standards*.610 CFR 830 Nuclear Safety Management
- DOE G 421.1-2 Implementation Guide for Use in Developing DSAs to Meet Subpart B of 10 CFR 830
- DOE Order 5480.23, Nuclear Safety Analysis Reports.

4.3 Safety-Class Structures, Systems, and Components

DOE-ID Order 420.D defines safety class as the SSCs for which responsibility must be taken, either preventive or mitigative, to meet the risk evaluation guidelines for the off-Site public.

The result of the analyses of bounding and representative unmitigated accidents in Section 3 is that doses to the off-Site public are within the risk evaluation guidelines. Therefore, there is no safety-class equipment for In Situ Grouting operations.

4.4 Safety-Significant Structures, Systems, and Components

Safety-significant SSCs are those that prevent or mitigate postulated abnormal scenarios that might result in a worker fatality, or are in the anticipated or unlikely frequency range that could result in the following consequences to immediate area or collocated on-site workers:

- Total effective dose equivalent more than 25 Rem
- Exposure to life-threatening concentrations of hazardous chemicals (>ERPG-3 levels)

- Exposure to explosion overpressures causing serious injury (>10 psi).

The only safety-significant SSC for ISG is the high-pressure grouting system. The grouting system contains sufficient stored energy to cause serious injury or death to a worker if it fails and sprays high-pressure grout or creates a projectile of failed equipment that could strike a worker.

4.4.1 High Pressure Grouting System

4.4.1.1 Safety Function. The safety function of the high-pressure grouting system is to contain the high-pressure grout within the system boundaries and assure grout is only released at high pressure when the nozzles are properly positioned beneath the ground surface. It is also to prevent a failure that will create airborne projectiles.

4.4.1.2 System Description. The grouting system must be capable of injecting grout at a specified rate into the soil matrix. The system will be designed for ease of cleaning grout injection nozzles using a water flush manifold in the glovebox.

A grout-receiving hopper will feed into an agitator and into the grout pump through high-pressure flexible lines to the drill stem and rotating cone bit. The cone bit injects the grout into the soil waste matrix as the drill stem is raised. The high-pressure flexible grout lines will lead from the grout pump to the drill rig mounted on the trolley. The drill stem grouting nozzle subassembly will be removable and replaced and/or cleaned in the glovebox using uncontaminated water.

The grouting system is being designed to incorporate operational safety. Features designed to protect workers from the hazards of high-pressure grouting system will include:

- Design that meets appropriate consensus standards for high pressure piping systems
- High-pressure relief valve and redundant pressure relief plug system
- Pressure gauges that operate smoothly at all pressures
- Pressure-rated equipment and fittings such as valves, hoses, and tie-downs
- Plugging-resistant nozzles
- Procurement, fabrication, and installation that meets the appropriate quality assurance requirements for this safety-significant item.

4.4.1.3 Functional Requirements. Functional requirements will be developed as part of designing the grouting system.

4.4.1.4 System Evaluation. Detailed design for the grouting system has not been completed at this time. The system will be designed to meet the performance and safety criteria. Meeting the functional requirements and implementing the appropriate procurement, fabrication, and installation quality requirements will ensure the system satisfies its performance requirements.

4.4.1.5 Controls. Quality assurance controls will be established for the design, procurement, fabrication, installation, and testing of the high-pressure grouting system.

Technical Safety Requirement and Surveillance Requirement controls will be established to verify the operability and condition of the protection features listed above. Limiting Conditions of Operation will be required to ensure the operability of the pressure relief system.

5. DERIVATION OF TECHNICAL SAFETY REQUIREMENTS

5.1 Introduction

This chapter defines Technical Safety Requirements (TSR) level controls to ensure safe operation during ISG. A new TSR will be required to verify operability and condition of high pressure grouting system protection features. Existing TSR requirements for procedures and training will ensure operating procedures include measures to prevent radiation exposure from high-radiation materials buried in the SDA.

5.2 Requirements

Technical Safety Requirements were derived from the following codes, standards, and Department of Energy (DOE) orders:

- DOE G 423.1-1 Implementation Guide for Use in Developing Technical Safety Requirements
- DOE-ID Order 420.D, Requirements and Guidance for Safety Analysis
- DOE Order 420.1A, Facility Safety
- DOE Order 5480.22, Technical Safety Requirements
- DOE-STD-3009, Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports
- 10 CFR 830, Nuclear Safety Management.

5.3 Technical Safety Requirement Coverage

This chapter of the PDSA addresses only TSRs proposed for ISG. When the final SAR is written, the TSRs will be completed and the RWMC TSR document will be revised to incorporate the ISG TSRs.

5.4 Derivation of Facility Modes

Operational modes will be derived as part of the final Safety Analysis Report.

5.5 TSR Derivation

5.5.1 Safety Limits, Limiting Control Settings, and LCOs

The grouting system is being designed to incorporate operational safety. An LCO level control will be required to ensure the system is inspected and maintained to protect workers from the hazards of high pressure grouting. Components that need to be addressed are:

- High-pressure relief valve and redundant-pressure relief plug system
- Pressure gauges.

5.5.2 SRs

No new surveillance requirements are anticipated.

5.5.3 Administrative Controls

No new administrative controls are proposed for ISG operations.

5.6 Design Features

The high-pressure grouting system includes passive design features to prevent system failure, including:

- Pressure-rated equipment and fittings such as piping, valves, hoses, and tie-downs
- Plugging-resistant nozzles.

5.7 Interface with Technical Safety Requirements from Other Facilities

Grouting will be performed at the RWMC's SDA. Thus, grouting operations will be under TSR-4, *Technical Safety Requirements for the Radioactive Waste Management Complex*. Grouting would also be encompassed by site-wide INEEL TSR controls contained in TSR-100, *INEEL Standardized Technical Safety Requirements Document.*

6. CRITICALITY PREVENTION

6.1 Introduction

This chapter summarizes the criticality safety analysis and the necessity for derived controls to prevent an inadvertent nuclear criticality at the Radioactive Waste Management Complex (RWMC) from in situ grouting operations. The criticality safety program for the Idaho National Engineering and Environmental Laboratory (INEEL), including the RWMC, and the basis for deriving operational criticality safety limits, are described in program requirements document (PRD)-112, Criticality Safety Program Requirements Manual.[1]

6.2 Requirements

The governing U.S. Department of Energy (DOE) requirements for nuclear criticality safety are contained in PRD-112,[1] which include requirements from DOE Order 420.1A, Facility Safety.[2] The DOE guidelines for preparing nonreactor nuclear facility criticality safety evaluations are contained in DOE-STD-3007-93.[3]

6.3 Criticality Concerns

6.3.1 Criticality Safety Principles and Criteria

The fundamental requirement for criticality safety is that before a new operation with fissionable materials begins, or before an existing operation changes, the entire process will be determined as subcritical under both normal and credible abnormal conditions.[4]

Criticality safety analysis is performed by evaluating fissile systems (normal and abnormal conditions) and comparing them against established acceptance criteria. The basic criteria are:

- **Application of the double contingency principle to determine limits of operation:** The double contingency principle recommends that sufficient safety factors be incorporated into design or procedures to require at least two unlikely, independent, and concurrent changes in process conditions (parameters) before a criticality accident is possible. No single failure shall result in the potential for a criticality accident. When controls cannot be applied to multiple independent parameters, a system of multiple controls on a single parameter is allowed. The number of controls required for a single controlled process parameter shall be based on their reliability and any features (e.g., shielding) that minimize the impact of their failure. The double contingency principle is applied to all credible criticality accident scenarios in determining the required design features and administrative controls to prevent an inadvertent criticality.

- **Passive engineered control**: Geometry control is the preferred control method. Where passive engineered control is not feasible, the preferred order of controls is active engineered controls followed by administrative controls.

- **A maximum calculated k-eff of 0.95 after a single failure:** When reliance is based on analytic methods rather than accepted experimental or handbook data, the calculated k-eff must include the uncertainties of the calculational method and consider the effects of credible accidents, corrosion, and tolerances.

The hazard analysis in Section 3.3 of this FS/PDSA identifies nuclear criticality as a potential hazard during ISG operations. The ISG treatment area contains many times the minimum critical mass of fissile material; however, the fissile materials in the buried wastes occur as contaminates at low concentrations. The evaluations[1] in Section 6.3.2 examine criticality safety issues associated with using ISG as a means of immobilizing the fissile material. For the criticality safety evaluations, only Pu-239 and not the uranium isotopes are included, since Pu-239 is by far the most reactive and abundant fissile material in the waste buried at the SDA.

6.3.2 Criticality Safety Evaluations

Grouting introduces the potential to create new criticality hazards by causing the buried waste or fissile nuclides in the waste to move, and by introducing grout to the waste matrix. Movement of the waste or fissile nuclides could concentrate the fissile materials in a manner that creates criticality concerns. Also, the grout can potentially change the criticality characteristics of the buried waste, particularly as a neutron moderator or reflector.

A criticality safety evaluation has been performed for ISG in the SDA.[5] This evaluation determined the concentration of Pu-239 in grout that would create a critical condition ($k_\infty +2\sigma = 1.0$ for infinite systems or $k_{eff}+2\sigma = 1.0$ for finite systems) for a variety of geometrical configurations and various grouting matrices. The cases evaluated were chosen to represent a range of conditions that might be result from grouting operations.

Five grout matrices were evaluated:

- A generic cementitious grout
- GMent-12 grout (cementitious)
- Tect-HG grout (cementitious with iron oxide)
- U.S. Grout (cementitious)
- Paraffin grout.

Three geometrical configurations were evaluated:

- Infinite system
- 55-gal sphere (approximates a 55-gal drum)
- 27-gal sphere (approximates half a 55-gal drum for generic cementitious and paraffin grout only).

Each geometrical configuration was evaluated for four grout conditions:

- Concrete grout with 50% water (wet grout)
- Concrete grout with 30% water (drying grout)
- Concrete grout with 10% water (dry grout)
- Paraffin grout.

The results of these analyses are shown in Tables 6-1 and 6-2.

Table 6-1. Pu-239 concentrations to achieve criticality for an infinite system.

Concentrations to Achieve Postulated Critical System Infinite System (k_∞+2σ =1.0) Generic Cementitious Grout Matrix		
Water Percent (wt%)	Pu Density (g/cm^3)	H/Pu Ratio
50	0.0063	3,092
30	0.0052	2,850
10	0.0040	1,982
Gment-12 Cementitious Grout Matrix		
50	0.0051	3,114
30	0.00414	2,514
10	0.00283	1,350
Tect-Hg Cementitious Grout Matrix		
50	0.00776	2,441
30	0.00839	1,658
10	0.00915	653
Cementitious U. S. Grout Matrix		
50	0.00572	3,116
30	0.00473	2,625
10	0.00342	1,441
Paraffin Grout Matrix		
na	0.0097	3,378

The same analyses were performed to determine the quantity of plutonium necessary to postulate the formation of a critical system for the finite configurations. The concentrations and quantities determined by these calculations will be compared to the Pu-239 levels that might occur in the MCS and the subsurface.

Table 6-2. Pu-239 quantities to achieve criticality for a finite system.

Concentrations to Postulate Critical System Finite System (k_{eff}+2σ =1.0) Volume 208 Liters (55-gallons) Generic Cementitious Grout Matrix			
Water Percent (wt%)	Pu Density (g/cm^3)	Finite Pu Mass (g)	H/Pu
50	0.0097	2,020	2,008
30	0.0100	2,080	1,527
10	0.0118	2,450	672
GMent-12 Cementitious Grout Matrix			
50	0.0096	1,997	1,654
30	0.0118	2,454	882
10	0.1115	23,192	34
Tect-Hg Cementitious Grout Matrix			
50	0.0123	2,558	1,540
30	0.0155	3,224	897
10	0.047	9,776	127
Cementitious U. S. Grout Matrix			
50	0.0099	2,059	1,801
30	0.0113	2,350	1,103
10	0.025	5,200	197
Paraffin Grout Matrix			
na	0.01125	2,340	2,913

6.3.2.1 Criticality in the MCS—To achieve criticality within the MCS requires a sufficient quantity of fissile material in a near optimal configuration, with near optimal neutron moderation, that is well-reflected and lacks other diluent/neutronic-absorbing material. Under normal operating conditions the only fissile material in the MCS will be Pu-239 mixed in the grout returns. Using the methods described in Chapter 3, the limiting source term for the calculated quantity of Pu-239 in the grout returns is 53.6 g and the concentration is 2.51×10^{-5} g/cm^3.[6] This number corresponds to an average fissile density that is homogeneously distributed over a specified volume. The water content of wet cementitious grout is approximately 50%, which dries to 10%.[7] The concentrations and quantities are below those shown in Tables 6-1 and 6-2 to achieve criticality. There is additional margin because the geometry of the grout is very different from the optimum sphere. The grout returns will be in a flat plane 15 × 15 ft with a variable depth that is nominally 5 in. Also, soil and waste materials will be mixed with the grout at unknown and highly variable concentrations; therefore, it is not credible to postulate the formation of a critical configuration in the grout return within the MCS.

Chapter 3 shows that microgram quantities of Pu-239 will become airborne in the MCS. Some may settle on flat surfaces or be trapped in the exhaust system HEPA filters. However, the very small quantities and lack of moderator indicate a criticality associated with airborne plutonium in the MCS is incredible.

For an explosion-type accident, the soil and waste may be expelled into the containment atmosphere; however, the Pu-239 will not be mixed with the grout that provides neutron moderation and will be scattered around the building or into the environment. Thus, the accident will not create conditions that could lead to a criticality, but will disperse fissile material thus effectively reducing the reactivity of the system.

There are no plans to bring waste to the surface as part of normal operations. Thus there is no concern for repackaging fissile material in a manner that will create criticality concerns.

6.3.2.2 Criticality in the Subsurface—Grout will be injected into the ground where it will surround, penetrate, and mix with the buried waste. The drill is expected to penetrate waste containers and the high-pressure jet of grout to mix with the waste and fill in voids. Because paraffin grout is more viscous and solidifies more slowly, it will be even more effective at flowing into and mixing with the grout.

As this grout injection process occurs, several situations could occur that would affect the reactivity of the fissile system:

- Some of the waste forms will remain intact and be undisturbed by grouting; however, as the grout surrounds the waste, the wet grout or paraffin will change the moderation and reflection of neutrons back into the waste mass. This could change the reactivity of the fissile material in the waste.

- Some Pu-239 will be mixed in the grout. This will create a mixture of grout and plutonium that is moderated by the water in the wet grout or by the paraffin and could increase the reactivity of the system.

As discussed above, the average concentration of Pu-239 in the grout is calculated to be $2.51 \times 10\text{-}5$ g/cm3. This average concentration is provided to develop a sense of the overall low concentration of fissile material over the areas being considered for grouting. It is expected that the fissile material will occur in more heterogeneous fashion throughout the waste zone. The water content of wet cementitious grout is approximately 50%, which dries to 10%.[7] The average concentrations are significantly below those shown in Tables 6-1 and 6-2 to achieve criticality for optimized grouted systems. Additionally, the expected fissile masses in any localized area, along with the need for near optimal moderation in a near optimal configuration and the necessity for there to be a lack of diluent/neutronic absorber material make the postulation of a critical configuration within a grouted system not credible. There is additional margin because the geometry of the grout is very different from the optimum sphere. Localized concentrations could be highly variable, ranging from zero to much higher. The dimensions could also be highly variable, ranging from a volume the size of part of a drum up to a large intrusion of grout several yards across. Also, soil and waste materials will be mixed with the grout at unknown and highly variable concentrations.

The calculational models developed in the criticality safety evaluation are very conservative.[5] Each of the models assumed fissile material to be distributed in an orderly, homogeneous manner at optimum concentrations within the buried waste. These models are not realistic and the optimized assumptions cannot occur in actual waste configurations, but were constructed to show the effect of each factor. In reality, the waste is distributed in a more heterogeneous manner within the waste zone. The presence of localized pockets of adequate fissile material to postulate a critical configuration is assumed.

Encountering localized pockets of pure fissile material not associated with some waste matrix is unlikely. Optimum geometrical configurations that are fully reflected by a tight-fitting reflector are assumed. Assuming optimum geometrical configurations is contrary to past excavation evidence that indicates degradation of the waste packages has occurred. This is also contrary to the actual waste forms and the way, in most instances, that waste packages were dumped into the SDA and mechanically compacted. The presence of other neutronic absorber or diluent material is ignored in the models. Ignoring the degradation of the package, and the nature of the waste in which the fissile material is for the most part associated with neutronic absorbers or diluent materials, is in itself very conservative. The necessity of these factors to exist in combination within the waste zone leads to the conclusion that a criticality is not credible in the SDA during the application of the ISG process.

The grouting matrices evaluated in the CSE were chosen as representative compositions for each of the various grout types. In most cases, the elemental compositions were given as a range between a maximum and a minimum. Slight variations to the elemental compositions of the actual grout matrices might provide slightly higher or lower concentrations and masses associated with the postulated critical configurations. These slight variances will not change the conclusions of the CSE.

6.3.2.3 Effects of ISTD Pretreatment—The possible criticality concern associated with grouting after pretreatment is that pretreatment will cause fissile materials to migrate and preferentially concentrate in a localized area. Although limited migration of fissile material within small-localized pockets could occur through several mechanisms, it is not expected that these mechanisms will create an unsafe condition by causing the preferential migration of fissile material. This limited migration of fissile material could occur due to the following.

- As gases are drawn into the heater/vacuum wells, they can carry fissile materials and deposit them in the subsurface matrix near the wells, in the sand layer between the outer casing and the heater can, or in the well header piping.

- Convection mechanisms associated with processes such as nitrate melting and destruction of organic compounds and combustible solids can cause fissile material migration.

- Large voids will be created that may produce localized concentrations near the void boundaries.

These mechanisms are not expected to create potentially critical conditions that are more severe than those already existing in the SDA or those associated with the grouting process itself. ISTD pretreatment will not introduce any new moderator into the system, and in fact may result in destruction of existing moderators such as polyethylene. It will also remove most of the water, which can function as a moderator. The fissile material migration mechanisms will not result in optimum shapes or the preferential concentration of fissile material into a critical configuration. Thus the above analysis is equally applicable to grouting in pretreated areas.

6.4 Criticality Controls

6.4.1 Engineering Controls

Based on the results of the analysis for ISG operations, an inadvertent criticality is deemed beyond extremely unlikely; therefore, no engineering controls are required.

6.4.2 Administrative Controls

Based on the results of the analysis for ISG grouting operations, an inadvertent criticality is deemed beyond extremely unlikely; therefore, no administrative controls are required.

6.4.3 Application of Double Contingency Principle

Satisfying the double contingency principle requires that at least two unlikely, independent, and concurrent changes in process conditions would be necessary before a criticality accident is possible. No independent failures are identified that can lead to an inadvertent criticality.

6.5 Criticality Protection Program

The INEEL criticality safety program provides the requirements for retrieval, handling, and storage of fissionable material. This program is based on applicable standards in current contractual requirements and implemented by appropriate INEEL policies, standards, and procedures. The INEEL has implemented an approved nuclear criticality safety program (i.e., PRD-112[1]) that is in accordance with DOE Order 420.1A.[2] The criticality safety program is followed for all project activities to ensure that fissile material is handled in such a way that a criticality accident is prevented and mitigated.

6.5.1 Criticality Safety Organization

The INEEL criticality safety program implements DOE Order 420.1A,[2] which applies to fissile materials that pose a criticality accident hazard. The program implements controls for fissile materials that are produced, processed, stored, transferred, disposed, or otherwise handled to ensure that the probability of a criticality accident is acceptably low. The program ensures, to the extent practicable, that the public, workers, property (both government and private), the environment, and essential operations are protected from the effects of a criticality accident. The nuclear operations facility management is responsible for establishing the criticality safety program. The criticality safety staff provides technical support for the criticality safety program. This includes documenting the requirements and recommendations of the criticality safety program and performing criticality safety evaluations and reviews to support facility safety analyses. Facility management is responsible for safe operations at facilities containing fissile material. Additional specific criticality safety responsibilities of nuclear operations management, facility management, and the criticality safety staff are identified in PRD-112.[1]

6.5.2 Criticality Safety Plans and Procedures

The criticality safety program has a wide array of safety plans and procedures currently in use throughout the INEEL. All operations and maintenance are governed by existing documentation, or additional plans and procedures are implemented. The procedures include all controls and limits specified in the criticality safety analysis. Procedures are supplemented with posted criticality safety limits, if required, and clearly designated evacuation routes.

6.5.3 Criticality Safety Training

The nuclear facility manager shall establish a program for selecting, training, and testing individuals and their functional supervisors who handle fissionable material. Training emphasizes that workers must understand and follow applicable safety procedure requirements. All workers handling significant quantities of fissile material (greater than 15 FGE) within nuclear facilities are trained in accordance with the criticality safety training program requirements included in PRD-112.[1]

6.5.4 Determination of Operational Nuclear Criticality Limits

Operational nuclear criticality limits are established based on the criticality safety principles and criteria, accepted handbook data, criticality safety calculations or evaluations, and criticality safety analyses prescribed in PRD-112[1] (see Section 6.3). Operational nuclear criticality limits are implemented as TSRs or safety requirements.

6.5.5 Criticality Safety Inspections and Audits

Criticality safety inspections and audits are conducted in accordance with PRD-112.[1]

6.5.6 Criticality Infraction Reporting and Follow-Up

Noncompliance with a criticality safety control is defined as any deviation from safety procedures that may affect the criticality safety or any activity involving fissionable materials. Reporting and follow-up criticality infractions are reported and documented in accordance with current INEEL procedures and manuals and DOE Order 232.1A.[8]

6.6 Criticality Instrumentation

In accordance with DOE Order 420.1A,[2] neither a criticality alarm system nor a criticality detection system is required in facilities where the probability of a criticality accident is determined to be beyond extremely unlikely. DOE Order 420.1A[2] states "reasonable ground for incredibility may be presented on the basis of commonly accepted engineering judgment." Based on the criticality safety analysis in Section 6.3, the probability of a criticality accident underground or in the ISG MCS is beyond extremely unlikely and, therefore, no criticality alarm system or criticality detection system is required for ISG operations.

6.7 References

1. PRD-112, 1998, "Criticality Safety Program Requirements Manual," Rev. 1, *Manual 10B–Engineering and Research*, Idaho National Engineering and Environmental Laboratory, June 1998.

2. DOE O 420.1A, 2002, "Facility Safety," U.S. Department of Energy, May 20, 2002.

3. DOE-STD-3007-93, 1998, "Guidelines for Preparing Criticality Safety Evaluations at Department of Energy Non-Reactor Nuclear Facilities," Change 1, U.S. Department of Energy, September 1998.

4. ANSI/ANS 8.1-1998, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," American National Standards Institute/American Nuclear Society, 1998.

5. Sentieri, Paul J., 2003, *Criticality Safety Evaluation for In Situ Grouting at the Subsurface Disposal Area*, INEEL/EXT-03-00638, Rev. 0, Idaho National Engineering and Environmental Laboratory, August 2003.

6. EDF-3418, "RWMC In Situ Grouting PDSA Accident Calculations," Draft, Idaho National Engineering and Environmental Laboratory.

7. INEEL, 2000, *Preliminary Criticality Safety Evaluation for In Situ Grouting in the Subsurface Disposal Area*, INEEL/EXT-2000-00794, Rev. 0, Idaho National Engineering and Environmental Laboratory.

8. DOE O 232.1A, 1997, "Occurrence Reporting and Processing of Operations Information," U.S. Department of Energy, July 21, 1997.

7. RADIATION PROTECTION

Chapter 7 of SAR-100[1] contains generic information for all documented safety analyses prepared by the INEEL and is applicable to this project. The following paragraphs provide additional information specific to ISG.

The soil cover will contain radioactive materials beneath the surface and will shield direct radiation. Very small quantities of radioactive materials will be brought to the surface in grout returns and on the drill string. Most of those will remain in the grout. The MCS also provides containment for any radioactive materials brought to the surface. The MCS design includes a sealing system that connects the MCS to the ground. The MCS ventilation system maintains negative pressure within the MCS. Its exhaust is filtered through HEPA filters and is monitored for radionuclides. Measures will be implemented under the radiation protection program to ensure no contamination release when the MCS is moved.

Normal grouting will be controlled from outside the MCS. Thus the radiation dose to operators is expected to be very low. The radiation protection program will prevent operators from entering the MCS during operations. Access for maintenance when the system is shut down will be controlled by the radiation protection program, and will require appropriate protective equipment.

7.1 References

1. SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," Rev. 0, June 27, 2000.

8. HAZARDOUS MATERIAL PROTECTION

Chapter 8 of SAR-100[1] contains generic information for all documented safety analyses prepared by the INEEL and is applicable to this project. The following paragraphs provide additional information specific to ISG.

The soil cover will contain hazardous materials beneath the surface. Very small quantities of hazardous materials will be brought to the surface in grout returns and on the drill string. Most of those will remain in the grout, although small quantities of volatile materials may become airborne. The MCS also provides containment for any hazardous materials brought to the surface. The MCS design includes a sealing system that connects the MCS to the ground. The MCS ventilation system maintains negative pressure within the MCS. Its exhaust is filtered through HEPA filters that will remove particulate hazardous materials. Measures will be implemented to ensure no hazardous material release when the MCS is moved.

Normal grouting will be controlled from outside the MCS. Thus the exposure to operators is expected to be very low. The RadCon Program will prevent operators from entering the MCS during normal operations. Access for maintenance when the system is shut down will be controlled by the RadCon Program, and will require appropriate protective equipment.

8.1 References

1. SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," Rev. 0, June 27, 2000.

9. RADIOACTIVE AND HAZARDOUS WASTE MANAGEMENT

Small quantities of radioactive and nonradioactive hazardous waste will be generated by ISG operations. Only small quantities will be generated because the ISG process does not remove buried waste from the ground. There will be some contaminants in grout returns and on the drill stem. The grout returns will remain in place on the surface and then be covered by clean grout and soil. Some low-level and possibly TRU radioactive wastes and hazardous wastes will be generated as part of monitoring, maintenance, operations, and other routine ISG activities. This chapter addresses how the ISG-generated wastes will be managed through the RWMC and INEEL waste management program. The RWMC and INEEL waste management programs are also described in Chapter 9 of the RWMC SAR.

9.1 Requirements

The applicable codes, standards, and Department of Energy (DOE) orders from which the safety criteria described in this chapter were derived are listed below:

- DOE Order 231.1, Environment, Safety, and Health Reporting
- DOE Order 435.1, Radioactive Waste Management
- DOE M 435.1-1, Radioactive Waste Management Manual
- DOE Order 5400.1, General Environmental Protection Program
- DOE-ID 10333 (00), DOE-ID INEEL Interim Pollution Prevention Plan
- DOE-ID 10381, Idaho National Engineering and Environmental Laboratory Waste Acceptance Criteria
- 40 CFR, Parts 260 through 279 (as applicable), Protection of Environment
- 40 CFR 302.4, Designation of Hazardous Substances
- 49 CFR Parts 171 through 177 (as applicable), Transportation
- State of Idaho Statutes, Title 39, Health and Safety, Chapter 44, Hazardous Waste Management, Idaho Code Section 39-4401 through 39-4431, 2000.

9.2 Radioactive and Hazardous Waste Management Program and Organization

Waste management planning for the ISG project will be developed if the project moves forward. Because ISG only produces secondary wastes, waste disposition should fit within current INEEL disposal practices, except possibly for small quantities of TRU waste that may be generated.

INEEL Manual 17, Waste Management, contains the controlling documents for the INEEL waste management program. All facilities and activities that generate a radioactive or hazardous waste stream must follow the requirements in this manual. The program includes an aggressive waste minimization and recycling program to reduce the quantities of waste generated.

At INEEL, the waste management program is managed by the Waste Generator Services (WGS) organization. Waste Generator Services works with RWMC personnel to ensure that all waste is properly identified, characterized, packaged, handled, stored, and disposed. In addition, WGS is responsible for defining and maintaining the program documents in Manual 17. The Integrated Waste Tracking System (IWTS) is a network application that assists personnel in tracking the creation, transportation, and disposal of hazardous, mixed low-level, and low-level waste.

A WGS facility representative is located at the RWMC and is supported by WGS specialists assigned to each specific waste stream. While RWMC has the ultimate responsibility for the wastes it generates, WGS personnel support characterizing the waste and planning for its disposition. The WGS representative performs the following functions.

- Pre-generation planning to prevent the generation of waste without appropriate controls
- Ensuring that waste-related hazards have been identified, their potential impacts analyzed and appropriate controls are in place
- Completing waste determination and disposition forms that document the life-cycle management of the waste, including process knowledge evaluation; additional waste determination, characterization, and verification; and selection of receiving facilities
- Coordinating with onsite or offsite receiving facility organizations for storage and treatment
- Making provisions for waste packages
- Certifying waste-to-waste acceptance criteria prior to transport in accordance with DOE Order 435.1
- Transporting waste in a consistent and compliant manner across the INEEL
- Completing final waste disposition, except for TRU waste.

As the responsible organization, RWMC must comply with all applicable requirements for regulated wastes per State and Federal regulations, DOE orders, company procedures, and the INEEL WAC.[1]

9.3 Radioactive and Hazardous Waste Streams or Sources

Because the radioactive and hazardous waste remains in the ground and under the soil cover during grouting, ISG should not produce large quantities of waste as part of the process. Small quantities of secondary low-level and TRU radioactive wastes, hazardous wastes, and mixed wastes may be generated during operations, monitoring, maintenance, and other routine ISG activities. An accident releasing radioactive material or hazardous material could increase waste-contaminated material generated during cleanup.

9.3.1 Waste Management Process

Because the project activities will be conducted under an OU 7-13/14 Record of Decision (ROD), prepared pursuant to CERCLA, all of the waste streams will be considered CERCLA waste. Even if the work is performed as a non-time-critical removal action, wastes will still be managed as CERCLA waste. While onsite, the waste is managed in accordance with the substantive requirements of the applicable or relevant and appropriate requirements (ARARs). Administrative requirements such as RCRA timeframes or reporting requirements do not apply to the waste while remaining in CERCLA storage, but may be implemented if required by internal INEEL procedures or may be adopted as best management practices. Generally, where CERCLA waste is shipped offsite to a treatment, storage, or disposal facility (TSDF), the waste must comply with all applicable regulatory requirements (administrative and substantive) including compliance with the CERCLA off-Site rule (40 CFR 300.440, "Procedures for Planning and Implementing Off-Site Response Actions").[2]

9.3.2 Waste Sources and Characteristics

9.3.2.1 Radioactive Waste

9.3.2.1.1 LLW—Radioactive waste may include contaminated grout splatters and soil, wipes used for radioactive contamination surveys, personnel protective equipment, decontamination wastes, and HEPA filters. Other LLW may include gloves, booties, respirator cartridges, and other PPE. Average annual LLW generation from 1998 through 2002 at RWMC has been 56 cubic meters. ISG should not add significantly to this amount.

9.3.2.1.2 TRU Waste—Some of the subsurface areas considered for ISG treatment contain buried TRU waste. TRU radionuclides may be brought to the surface creating TRU waste. The most likely sources would be from decontaminating surfaces inside the MCS. Another likely source is HEPA filters from the MCS Ventilation System.

9.3.2.2 Sources of Hazardous Waste. Potential hazardous wastes are hydraulic fluids, oil, and solvents. Average annual hazardous waste generation from 1998 through 2002 was 71 cubic meters. In situ grouting should not significantly increase this amount unless there is an accident. Cementitious and paraffin grouts are not hazardous materials.

9.3.2.3 Sources of Mixed Waste. Since ISG is treating both radioactive and hazardous buried waste, there is potential for the radioactive and hazardous wastes discussed above to become mixed waste.

9.3.3 Waste Handling or Treatment System

9.3.3.1 Radioactive Waste

9.3.3.1.1 LLW—Most LLW is disposed at the RWMC without treatment. However, LLW may be sent offsite for treatment and/or disposal. All LLW offered for commercial treatment and/or disposal by RWMC is characterized and certified to meet the waste acceptance criteria (WAC) at the commercial treatment and/or disposal facility.

9.3.3.1.2 TRU Waste—No TRU waste is currently generated at RWMC as a result of facility operations; however, plans are being developed to dispose of TRU waste generated by the Glovebox Excavator Method Project. These plans include storing at the INEEL in a RCRA permitted storage area, processing through the Advanced Mixed Waste Treatment facility, and shipping to the Waste Isolation Pilot Plant. A similar approach could be implemented for ISG-related TRU.

9.3.3.2 Hazardous Waste. Treatment of hazardous waste generated at RWMC can be conducted either at RWMC (generator treatment) or at a permitted TSDF. Treatment at a permitted TSDF is used most often. Hazardous waste is packaged per the WAC for the offsite TSDF and applicable regulations. Waste Operations personnel arrange for transportation to the permitted TSDF.

9.3.3.3 Mixed Waste. Mixed waste is placed in RCRA-approved temporary storage areas and then collected and shipped offsite to licensed disposal facilities.

9.3.4 Normal Emissions

Further work is needed to determine if exhaust ventilation is a normal emission and if it would require permitting.

9.4 References

1. DOE-ID, 2002, *Idaho National Engineering and Environmental Laboratory Waste Acceptance Criteria*, DOE/ID-10381, Rev. 16, U.S. Department of Energy Idaho Operations Office, December 2002.

2. 40 CFR 300.440, 2003, "National Oil and Hazardous Substances Pollution Contingency Plan," Section 440, "Procedures for Planning and Implementing Offsite Response Actions," *Code of Federal Regulations*, Office of the Federal Register, May 2003.

10. INITIAL TESTING, INSERVICE SURVEILLANCE, AND MAINTENANCE

Chapter 10 of SAR-100[1] contains the information that is generic for all documented safety analyses prepared by the INEEL. This information is applicable to ISG.

It is planned to conduct a test program for the ISG concept in a non-hazardous environment before the system is deployed at RWMC. Details of this test program are under development. Results from the test program will be factored into the final system design and Documented Safety Analysis.

The effectiveness of the high pressure grouting system, which is a safety-significant SSC, will also be tested after the system is installed at the RWMC and before ISG operations begin.

10.1 References

1. SAR-100, “INEEL Standardized Safety Analysis Report (SAR) Chapters,” Rev. 0, June 27, 2000.

11. OPERATIONAL SAFETY

Chapter 11 of SAR-100[1] contains the information that is generic for all documented safety analyses prepared by the INEEL. The following information is specific to ISG.

11.1 Fire Protection

A Fire Hazard Analysis will be performed before ISG is implemented at RWMC. Because no excavations are planned and the waste will remain beneath the SDA surface, a fire in the waste is considered extremely unlikely.

The MCS and the grouting equipment are constructed of nonflammable materials; however, the drilling equipment inside the MCS contains hydraulic fluid, which is flammable. Also, if diesel-powered equipment is used outside the MCS, the diesel fuel will be flammable.

Another potential fire source is paraffin grout if it is used. The paraffin will be heated to liquid form. The melting temperature is 125–130°F. The flash point is 455°F, so the paraffin grout will not be heated near the flash point to achieve melting. The paraffin grout has an NFPA flammability hazard level of 1. Cementitious grout will not burn, and thus is not a fire hazard.

The Fire Hazard Analysis will address these concerns and appropriate controls implemented.

11.2 References

1. SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," Rev. 0, June 27, 2000.

12. PROCEDURES AND TRAINING

Chapter 12 of SAR-100[1] contains the information that is generic for all documented safety analyses prepared by the INEEL. The information in Chapter 12 of the INEEL SAR is applicable to ISG.

12.1 References

1. SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," Rev. 0, June 27, 2000.

13. HUMAN FACTORS

The purpose of this chapter is to address the human-machine interface associated with safety-significant SSCs. The safety-significant system for ISG is the high-pressure grouting system. This system requires routine surveillance and maintenance, but does not involve human interaction and control to drill holes and emplace grout. Thus, no human factors analysis is needed for this system.

Emplacing grout involves the control systems for drill rig placement and operation and for grout injection. At this time, the design of these systems is not sufficiently developed to assess human factors. This information will be developed as the design progresses.

14. QUALITY ASSURANCE

Chapter 14 of SAR-100[1] contains the information that is generic for all documented safety analyses prepared by the INEEL. The information in Chapter 14 of the INEEL SAR is applicable to ISG.

Quality Assurance controls will be required for the design, procurement, fabrication, and installation of the safety-significant high-pressure grout system. These will be managed in accordance with the INEEL Quality Program.

14.1 References

1. SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," Rev. 0, June 27, 2000.

15. EMERGENCY PREPAREDNESS PROGRAM

Chapter 15 of SAR-100[1] contains the information that is generic for all documented safety analyses prepared by the INEEL. The information in Chapter 15 of the INEEL SAR is applicable to ISG.

15.1 References

1. SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," Rev. 0, June 27, 2000.

16. PROVISIONS FOR DECONTAMINATION AND DECOMMISSIONING

Chapter 16 of SAR-100[1] contains the information that is generic for all documented safety analyses prepared by the INEEL. The information in Chapter 16 of the INEEL SAR is applicable to ISG.

16.1 References

1. SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," Rev. 0, June 27, 2000.

17. MANAGEMENT, ORGANIZATION, AND INSTITUTIONAL SAFETY PROVISIONS

Chapter 17 of SAR-100[1] contains the information that is generic for all documented safety analyses prepared by the INEEL and describes the site-wide management, organization, and institutional safety provisions, which are applicable to ISG. Specific management, organization, and institutional safety provisions pertaining to RWMC are described in this chapter of the main body of the RWMC SAR. This information is applicable to the project. Details on management for implementation of ISG will be developed in the future and included in the DSA.

17.1 Reference

1. SAR-100, "INEEL Standardized Safety Analysis Report (SAR) Chapters," Rev. 0, June 27, 2000.